VOL. 5

United States of America, }
Northern District of Illinois, } ss.
Eastern Division. }

IN THE

District Court of the United States

UNITED STATES OF AMERICA,
Complainant,
vs.
THE SANITARY DISTRICT OF CHICAGO,
Defendant,

C. C. No. 29,019, and Equity No. 114.

RECORD OF TESTIMONY AND PROOF TAKEN BEFORE COMMISSIONERS APPOINTED TO TAKE TESTIMONY IN SAID CAUSE.

Appearances:

Mr. James H. Wilkerson,
United States Attorney, and
Mr. Albert L. Hopkins,
Assistant United States Attorney,
For Complainant.

Mr. Edmund D. Adcock and
Mr. Alfred S. Austrian,
For Respondent.

1914
THE GUNTHORP-WARREN PRINTING COMPANY
CHICAGO

VOL. 5

INDEX TO WITNESSES

COMPLAINANT'S

1913-1914

J42960

UNITED STATES OF AMERICA,
NORTHERN DISTRICT OF ILLINOIS, } ss.
EASTERN DIVISION.

IN THE

District Court of the United States

UNITED STATES OF AMERICA,
Complainant,
vs.
THE SANITARY DISTRICT OF CHICAGO,
Defendant,

C. C. No. 29,019.

Depositions in the above entitled cause, taken pursuant to notice, before the Commissioner, at the Federal Building, Detroit, Michigan, beginning on Tuesday, February 3, 1914, at 10:30 A. M.

Present:

Mr. James H. Wilkerson and Mr. Albert L. Hopkins, representing the Government.

Mr. Edmund D. Adcock and Mr. Alfred S. Austrian, representing the Sanitary District.

TESTIMONY IN REBUTTAL ON BEHALF OF THE GOVERNMENT.

EUGENE E. HASKELL, a witness called in rebuttal on behalf of the Government, was first duly sworn and testified as follows:

Direct Examination by Mr. Hopkins.

Q. Mr. Haskell, you testified in this case before in February, 1909?

A. I did.

Q. Since that time, what further qualification have you had, in connection with hydraulic engineering?

A. I have been connected with the question of regulation of lake levels, in connection with my duties as a Commissioner of the International Waterways Commission.

Q. What has been your business since your last testimony?

A. I have been engaged with one of the Canadian members upon the completion of the report which the Commission put out, the title of which is the "Regulation of Lake Erie."

Q. You are connected with Cornell University still?

A. Yes.

Q. In what capacity?

A. Director of the College of Civil Engineering.

Q. And that includes what?

A. I have supervision of all departments of the college.

Q. With reference to the laboratory?

A. All of them; the hydraulic laboratory is a department of the college.

Q. Have you had any further employment since that time, that you have not mentioned?

A. I have mapped out a course of procedure for the Canadian Government, this last summer, to enable them to obtain some data in relation to the hydraulics of the St. Lawrence between Montreal and Quebec.

Q. Since your testimony in February, 1909, have you learned that there have been other measurements of the Niagara River?

A. I have; other measurements made by the United States Lake Survey.

(Chart produced and marked Haskell's Exhibit 1, February 3, 1914, for Identification.)

Q. I show you this chart marked Haskell's Exhibit 1 of this date for Identification, which purports to have on it all of the measurements made by the Lake Survey of the Niagara River, including 118 observations, which you did not have before you when you gave your former testimony. Assuming that the plat is correctly plotted, and assuming that the observations were taken correctly, do you wish to make any further statement in regard to the degree of correctness of the measurements of the Niagara River flow? Assume further, Mr. Haskell, that the 118 measurements were taken at the International Bridge Section, in the years 1907 and 1908?

Mr. Shenehon: This chart shows plotted the individual observations made at the International Bridge Section of the Niagara River; 101 observations made in 1898 to 1900, inclu-

sive, and 118 individual observations made in the years 1907 and 1908, as reported in the report on the Preservation of Niagara Falls, and already referred to in this case.

In addition to the plotting of these individual observations, there is indicated by a black square the mean volume of flow and mean gage level of 121 measurements on the Niagara River made at the Open Section, and already in evidence in this case. Those were made in 1899 and 1900.

In addition, indicated by a black triangle are shown the ten measurements of the Third Section made during the year 1913, the summer of 1913.

Mr. Adcock: What do you call that section?

Mr. Shenehon: We have spoken of it as the Third or Split Section. It is the mean of the measurements.

Mr. Hopkins: Q. Now Mr. Haskell, incorporating the statement just made as to what the plat shows into the question, and assuming it has been correctly plotted and the observations were made correctly, do you now wish to make a further statement with reference to your former testimony as to the degree of accuracy of those measurements?

A. Yes. The additional observations extend our knowledge of the discharge of the Niagara. They confirm the previous observations, and I would consider it perfectly proper to reduce the limits of error which I gave in my previous testimony.

Q. In coming to that conclusion, do you take into consideration the checks between the various sections?

A. Yes.

Q. What are those checks?

A. The Bridge Section and the Open Section agree within about 1 per cent. These new observations made on the Split Section fall between those two, agreeing within about ½ of 1 per cent of either of the other.

Q. Is that indicated on the chart?

A. They are indicated on this chart.

Q. What is your conclusion as to the accuracy of the work?

A. Why I should state that we knew the position of this center of gravity of the observations here within ½ of 1 per cent.

Q. You mean by that do you that we know the volume of flow of the Niagara River within the percentage that you have indicated?

A. For that particular point, for the stage which corresponds to that.

Q. Taking into consideration the three sections in that?
A. The three sections.
Q. What increment is shown by that?
A. It is given on here as 21,900 per foot.
Q. What degree of precision do you think that increment represents?
A. For this particular river, I should say it was within 2 per cent.
Q. What elements do you consider in making up your mind as to that degree of precision of the measurements of the Niagara River; for instance, first, as to cross section?
A. Why the determination of the cross section could be made with great accuracy.
Q. Within what percentage would you say?
A. Easily within ½ of 1 per cent.
Q. Now the co-efficient work?
A. That can easily be determined within ½ of 1 per cent. The records will show that.
Q. What is your opinion as to the degree of accuracy of the straight line method as adopted on that chart?
A. Why that represents the observations very closely indeed within the range given here.
Q. Are you acquainted with the volume of flow as measured by the Lake Survey in the St. Clair River?
A. I have seen the results of the observations which have been made there.
Q. Do you know what sections were measured in the St. Clair River?
A. I understand that they have recently measured discharges up in what is known as the Gorge Section near the head of the river; and that they have also measured the discharge in the several outlets in the Delta.
Q. Do you know how closely those various sections check?
A. Why they check very closely indeed, I believe.
Q. Can you give it in percentage?
A. No, I don't know that I can give it. As I recall it, it was within a very small percentage.
Q. Do you understand it is within 1 per cent?
A. Yes, I should say it was within 1 per cent.
Q. Now, do you have an opinion as to the accuracy with which we know the volume of flow in the St. Clair River?
A. For the center of gravity of those observations, for the stage corresponding to that, I should say we knew the flow within 2 per cent.

Q. Are you familiar with the various measurements of the St. Lawrence River?

A. I am not familiar with them excepting those that were made in the early days, 1900, 1901.

Q. Having those in mind, do you have an opinion as to the accuracy with which the Lake Survey knows the volume of flow in the St. Lawrence River?

A. Within the center of gravity of those observations that were made by Mr. Shenehon, while he was in charge of that party, I should say that we knew the position of that point within 3 per cent.

Q. In your work on the International Waterways Commission, did you have occasion to compute an increment for the St. Clair River?

A. Yes.

Q. What was the increment computed for mean lake stage?

A. For mean stage, 18,900.

Q. Do you still think that is correct?

A. I see no reason to change my opinion in that regard.

Q. How long have you been engaged in and studying the measuring of streams?

A. Thirty years this next summer.

Q. What is your opinion as to the practicability of measuring large streams?

A. They can be measured with great accuracy.

Q. Within what degree of accuracy?

A. Easily within 1 per cent, if you are willing to put the necessary labor on them.

Q. Do you have an opinion as to whether or not large streams can be measured as accurately as small streams?

A. I should say equally so.

Q. Within what degree of precision can the area of a cross section be determined?

A. Within ½ of 1 per cent.

Q. Within what degree of precision can the velocity coefficient be determined?

A. Within ½ of 1 per cent.

Q. With what degree of precision does the Haskell Meter register?

A. In Open Channel work, easily within ½ of 1 per cent.

Q. Suppose the water is highly perturbed, what effect do you think that would have upon the registration of the Haskell Meter?

A. It would undoubtedly under-register.

Q. To what extent?

A. Very small per cent.

Q. Can you give it more definitely?

A. I should say within 1 per cent.

Q. Is that the highest state of perturbation?

A. Well, there are cases where in a high state of perturbation of the water no meter has applicability.

Q. Take the conditions in the Niagara River, within what degree of precision will the Haskell Meter register there?

A. Within 1 per cent.

Q. Will you just explain further what you are taking into consideration in the Niagara River itself, in saying that it will be within 1 per cent; first, is it with reference to the International Bridge Section?

A. Do you refer to cross section, is that the point you wish to bring out? Or do you mean all of the processes right straight through, by which we arrive at the discharge?

Q. Take the Open Section, as we have spoken of it, with what degree of precision do you think the Haskel Meter would register in that Open Section?

A. In measuring velocities? Within ½ of 1 per cent.

Q. Take the Bridge Section?

A. The same is true there.

Q. And the Third Section?

A. The same is true there.

Q. What effect does an oblique current have upon the meter?

A. The velocity measured would be too large.

Q. So that if there were an under-registration of the meter, if the currents were all oblique, they would tend to compensate?

A. That would be the tendency.

Q. Are you acquainted with the Niagara River, and the condition of the water in the Niagara River?

A. I am.

Q. Specifically at the Bridge Section, will you describe the conditions there?

A. The International Bridge lies within ⅛ of a mile of the center of a two-mile stretch that is very uniform in width and the flow is very regular through that reach.

Q. With reference to the regimen of the river, is it good or bad for measuring?

A. It is good.

Q. And with reference to the piers of the bridge, what effect do they have?

A. The piers, of course, divide the water at those par-

ticular points as it comes down, and there is a tendency to create eddies next to the piers, on both sides.

Q. To what extent do you think that that eddying water will affect the whole result of the measurement, in percentage if you can give it?

A. Oh, not to exceed ½ of 1 per cent.

Q. Are you acquainted with Mr. Shenehon's report of 1900, in regard to that measurement?

A. Yes, I am.

Q. Do you think that his allowance for the eddying around the piers was proper and accurate?

A. I think it is a very fair allowance.

Q. Did you personally put some time in on that work?

A. At the beginning of those observations?

Q. Yes.

A. I began that work on the Niagara River in 1897.

Q. Did you examine those sections prior to their selection for this purpose?

A. Yes.

Q. You selected this section for measurements at the bridge, didn't you?

A. I did.

Q. Who was with you at the time?

A. Mr. George Y. Wisner.

Q. Both of you agreed that that was a proper section for measurement?

A. We did.

Q. Will you describe generally the Open Section in reference to its being a proper place for measurement?

A. The Open Section is about 1,800 feet below the bridge and in a very good reach of river for discharge work.

Q. Is there any turbulence or degree of perturbation that would affect the work?

A. There is none.

Q. Now have you seen what we call the Split Section on either side of Grand Island, where the river measurements by Mr. Richmond were made?

A. I visited that section on the 5th of January with Mr. Shenehon.

Q. Will you describe the conditions at those two sections?

A. The two sections are very good ones indeed. When there we took some photographs. Here is a photograph of the section on the west side of Grand Island, taken from the west side of the channel, looking east across the section.

(Witness producing photograph.)

Q. There is a curve there, isn't there?

A. The river is curving.

Q. What effect does that have on the location?

A. Practically nothing; the curve is of too long a radius.

Q. Now do you know the condition in either section above this place with reference to a sand bar?

A. In the east channel there is a bar above the section.

Q. What effect do you think that would have upon the section measured, as to whether it can be accurately measured?

A. Practically nothing, if the vertical curves were determined with the accuracy that they should have been.

Q. What effect does the rating of the meter have in this measurement of rivers?

A. We have to rate a meter in order to get the equation for converting revolutions per minute or per second made by the wheel into velocity.

Q. How important is the accurate rating of the meter?

A. The meter has to be accurately rated, in order to get accurate results.

Q. What is the most accurate way of rating a meter?

A. By drawing it through still water.

Q. How about using colored water in the stream that you are measuring?

A. For testing the accuracy?

Q. As a test of the accuracy?

A. It is the most accurate way that I know of for getting a comparison.

Q. Are you acquainted with the tests made by Mr. Shenehon in the Detroit River?

A. I am.

Q. What was that done for?

A. For the purpose of ascertaining how accurately the meters indicated the truth.

Q. What was the result?

A. That they were very accurate.

Q. What percentage do you mean when you say "very"?

A. That is less than ½ of 1 per cent; the results, as shown by his report upon that work and published in Senate Document Number 105, 62nd Congress 1st Session, in the paper, "The Preservation of Niagara Falls."

Q. Do you know of some tests made of the Haskell Current Meter by Doctor Mendenhall?

A. I do.

Q. Will you tell us what those tests were?

A. During the fiscal year 1890, 1891, while with the Coast

and Geodetic Survey, I was engaged in ascertaining deep sea depths and temperatures upon the coast survey steamers; and we used two different types of meters, that is the Haskell-Ritchie Direction Current Meter, and what is known as the Pillsbury Meter, which was a cup meter. The results obtained by the two did not agree, and Doctor Mendenhall, then superintendent of the Coast and Geodetic Survey, wanted to satisfy himself as to the reliability of those observations, he arranged for a test which was made from the Coast and Geodetic Survey steamer Blake in Vinyard Sound, in July or August, I won't be certain which, in 1891.

The method used by Doctor Mendenhall was that of determining the velocity of the current, which was a tidal one, by means of floats. The current meter was run for an interval of ten minutes at a five foot depth, and during that time at intervals of a minute each can float was run at the same immersion, and the velocity as derived from the mean of the ten floats was used to check the meter. The meter used had been rated some two months before that test, and the results of that rating are given in this pamphlet I hold in my hand, on page 8.

(Pamphlet identified by the witness was here marked Haskell's Exhibit 2, February 3rd, 1914, for Identification.)

Q. This is a pamphlet entitled: "Ritchie-Haskell Direction-Current Meter and the Haskell Current Meters"; and you are referring to what page?

A. That is page 7.

Mr. Austrian: Is that a government document?

A. No. The results of that comparison, of a part of the observations are shown on this page, the marked paragraph on page 8.

Mr. Hopkins: Just read the part you have in mind.

A. These observations are in feet per second, and are arranged in the order of float, meter; that is the velocity given by the float followed by that given by the meter: 1.04, 1.05; 1.29, 1.28; 1.55, 1.55; 1.94, 1.96; 2.56, 2.59; 2.65, 2.64; 2.76, 2.74; 2.80, 2.82; 3.08, 3.11.

Q. Now were there some tests made of this meter in Philadelphia?

A. The city of Philadelphia used them a number of years ago in determining the efficiency of some new pumps which they had contracted for.

Q. What test did they make and with what result?

A. They built a canal into which to discharge the capacity of the pumps, and in that canal placed a weir for measuring

the volume of the flow, and they also measured the volume of flow with these meters. The results of the two gave an agreement within, as I recall it, about 1 per cent. It has been some time since I have seen those figures.

Q. Are you familiar with an article by Mr. B. F. Groat, published in the proceedings of the American Society of Civil Engineers?

A. I have read it.

Q. With reference to this meter?

A. With reference to this meter, yes, sir.

Q. What is your opinion as to the soundness of the opinions given by Mr. Groat?

A. I think it is an admirable paper.

Mr. Hopkins: This article is already in and has been read from many times; it is in evidence.

Mr. Austrian: Q. What year was that?

A. December, 1912.

Mr. Hopkins: It is paper number 1259, page 819 of Volume 66.

Mr. Austrian: And the date?

Mr. Hopkins: 1913.

Q. Are you acquainted with Mr. Schoder and Mr. Turner of the engineering department of Cornell University?

A. I am.

Q. What is their position at Cornell, and their relation to you in that regard?

A. They are both assistant professors in the department of hydraulics. Mr. Turner is an assistant professor of the First Grade, and Mr. Schoder is an assistant professor of the Second Grade.

Q. Is their work in the laboratory under your direction?

A. It is.

Q. Have you read their testimony in this case?

A. I have.

Q. Did you take any part in the tests made by them?

A. I did not.

Q. Do you have any comments to make upon the results obtained by them, as appears in that testimony?

A. I should not be willing to accept them.

Q. What probable errors occurred in that rating and testing?

A. *Why they attribute everything to the meter.* They claim to know the discharge of that standard weir within 1 per cent. I doubt it. I think if it is known within 2 or 3 per cent, it is as close as is safe.

Q. In the question of the rating of the meter, what error do you think might occur there?

A. I should think it might well happen that there is an error of 2 per cent in the rating of that meter.

Q. Why?

A. I base my estimate on that upon the time at which all those observations were made.

Q. How about the number of observations in the rating?

A. I don't know how many were made, but I doubt very much indeed enough having been made to give a true determination of the rating.

Q. How about the experience of the men in the work they were doing?

A. The only experience that they have had is simply that in connection with student instruction in the laboratory, and in a few occasions they have gone out and measured open channels, so as to give students a little further knowledge of work of that character.

Q. Mr. Turner did some work with the Lake Survey, didn't he?

A. Mr. Turner was the Recorder of the Lake Survey for a little over a year, when I was Principal Assistant Engineer.

Q. Did you notice in that testimony that Mr. Schoder said that he had measured certain streams, one of which, I think was the Susquehanna, and the length of time that they took in the measurements? What is your opinion as to the accuracy of any such work as that, within the time mentioned?

A. It would take a month to get anything like a determination of the flow of that stream at that particular stage, which was a very low stage.

Q. Now, returning to the canal, what error if any might occur in the measurement of the area of the cross section?

A. It would be a difficult matter to determine the area of the cross section accurately in that perturbed water.

Q. Having in mind the photographs which are exhibits to their testimony, what degree of precision do you think they could reach in measuring the cross section?

A. In the perturbed water which is shown just below the baffles in Exhibits 4 and 5, 2 and 3, 6 and 8 and 9 and 10, it would be very difficult to determine the accuracy within 5 per cent.

Q. What was the depth of the water, as you understood?

A. Somewhere in the neighborhood of 3½ feet.

Q. Now with reference to determining the co-efficients of

the work as testified to by Mr. Schoder and Mr. Turner, what is your opinion as to the error that might occur there?

A. Oh, they could easily be in error 2 or 3 per cent in the determination of those.

Q. Any more than that?

A. Well, there might be more than that. It would depend entirely upon the time that was devoted to it.

Q. About the turbulence of the water in that canal, in comparison with the water in the Niagara River, or any other of the rivers we have been considering, the St. Clair, the Detroit and the St. Lawrence, at the sections which have been measured, what have you to say?

A. There is nothing in common between the two; that is in this case the perturbation is caused by the water dropping over a weir. The standing weir there is 9¼ feet high. There is nothing of that kind in connection with any of the discharge sections on the several lake outlets.

Q. The mere fact that there are baffles in there would not smooth it out?

A. It of course helps to still the water.

Q. How would you describe the condition of the water in the canal itself, as shown by the photographs?

A. Up near the baffles there, it is very much disturbed.

Q. It is practically a rapids?

A. Yes, practically a rapids.

Q. What is your opinion as to the applicability of the conclusions reached by these gentlemen, Mr. Schoder and Mr. Turner, with reference to the measurements that have been made by the Lake Survey in the Niagara, St. Clair and St. Lawrence Rivers?

A. I do not know that I quite get your point.

Q. (Question read.)

A. They are not at all applicable.

Q. Did you see the exhibit of Mr. Turner with reference to vertical curves in the St. Marys River?

A. I saw that blue print which you have here.

Q. Do you know whether that is an authentic record of the Lake Survey?

A. No, I do not.

Q. What is your conclusion as to that exhibit, with reference to the point it is introduced for?

A. There is nothing in it at all.

Q. Why?

A. He undertakes to compare two vertical curves and to point out the discrepancy between them, and attribute that to

the meter. We know there is a discrepancy even greater than what is shown there in the determination of vertical curves, and particularly vertical curves determined under the ice, as those were.

Q. With reference to their being at the same or different times?

A. Why, you see the two which he tries to compare were taken at entirely different times. They are not comparable at all.

Q. With reference to velocities, whether they were the same or different?

A. The velocities, I think there is some little difference in that.

Q. Was the method used there as referred to by Mr. Turner the same as that used in the Niagara?

A. No, it was not. That work in the St. Marys River through the ice all depends upon one meter, that is the use of one meter in determining all of the vertical curves and all of the discharges. In the later work, we used two or more meters so as to have a check.

Q. Do you have your former testimony before you, Mr. Haskell?

A. I have a copy of it here.

Q. Referring to that part of your testimony which appears on page 67 of the corrected paging with reference to dependence to be placed upon data of evaporation, in the light of further study, do you wish to change that?

A. I see no reason for changing it. Nothing has happened, so far as I know, to throw any greater light on that problem.

Q. What is your opinion as to the propriety of taking certain data in reference to percentage of run-off from areas in Massachusetts, Western Pennsylvania and New York, where the conditions are either hilly, sandy or wooded, and applying them without change to the Lake Erie basin, with reference to run-off and evaporation and so on?

Mr. Adcock: I object to that. I do not think the conditions incorporated in the question have been shown.

Mr. Hopkins: Q. First I will ask you then, what is your opinion as to the propriety of taking conditions of run-off in any locality, and applying them to another?

A. It certainly would be open to great uncertainty.

Q. And then if your data are taken from a territory as described in the prior question—are you familiar with the Lake Erie run-off basin?

A. Why, yes; with all of them for that matter.

Mr. Hopkins: Then I ask for an answer to my first question in reference to that.

Mr. Adcock: My objection to that was that the condition stated in your question does not appear in any part of the record.

Mr. Hopkins: Read the question.

(The question was read.)

Mr. Wilkerson: Your objection is it does not appear what kind of territory that is?

Mr. Adcock: Yes.

Mr. Wilkerson: Assuming that the conditions are as stated in the question.

Mr. Adcock: That is all right.

Mr. Austrian: As stated in what question; assuming the conditions are as incorporated in what question?

Mr. Hopkins: The question just read.

Q. Assuming the conditions of the districts named are as I have stated, either hilly, sandy or wooded, then what is your opinion as to the propriety of taking that data and applying it to the Lake Erie basin?

A. I do not think you could apply the data with any degree of certainty or accuracy.

Mr. Wilkerson: On that question, we might as well settle it right now, is there any dispute as to the physical characteristics of the territory in which these measurements of run-off were made; any dispute about the physical characteristics of New England?

Mr. Austrian: Each one was described.

Mr. Adcock: Each one was described, the conditions were described.

Mr. Hopkins: As far as that is concerned, let it stand. Mr. Stearns describes it.

Mr. Adcock: Do you want to ask him about that?

Mr. Hopkins: He has not read it.

Mr. Wilkerson: Then it is straightened out, because the testimony of Mr. Stearns is in accordance with the assumption in Mr. Hopkins' question.

Mr. Adcock: No, I do not think so.

Mr. Wilkerson: That is a matter of argument.

Mr. Adcock: If the assumption made in the question were in accordance with the testimony, it might apply.

Mr. Wilkerson: If the facts are already in the record, it is a matter of argument.

Mr. Austrian: That is if the witness knows the facts upon which Mr. Stearns based his testimony.

Mr. Wilkerson: The witness has based his answer on the question assuming the facts are as stated.

Mr. Hopkins: Q. Mr. Haskell, referring again to Mr. Groat's tests, just what were his tests of the meter, and what is your opinion as to his method?

A. So far as I can gather from his paper, I think the test a perfectly fair one, and a good one. That is the water dropped through the turbines into the tail race, and he had stilling racks above the sections which he was measuring; and his results are set forth in his report, in his paper I should say.

Q. Will you refer to the details of this particular test, as they appear in that report?

A. Yes, I will. I should refer to this paragraph marked "6," in his paper.

Q. What page?

A. It is page 821 in the report which has been referred to, referring to Proceedings of the American Society of Civil Engineers, Volume 38, number 10, of December, 1912, page 1663.

Mr. Adcock: What was that reference, page 821?

Mr. Hopkins: That was in a different book, same article.

(Paragraphs 3 and 6 in paper referred to are as follows:)

"3." "In the foregoing sense, a cup meter is affected relatively to a much greater extent than a screw meter. In the tail races at Massena, as an average, the cup meter was affected to the extent of 6 per cent, while the Haskell Meter was affected mostly by less than 1 per cent. In boilers of considerable violence the cup meter may easily over-register by 25 per cent, while the screw meter will under-register by not more than 3 or 4 per cent.

"6." The average corrections thus obtained for the Haskell Meter when run with the Gurley-Price Meter in the tail races at Massena varied from 0.5 to 0.9 of 1 per cent, while the corresponding corrections for the Gurley-Price Meter were about six times larger. Comparisons with the Pitot Tube furnished the same corrections substantially as those obtained by comparison of the meters."

The Witness: Mr. Groat's conclusions are set forth in that paragraph, and he refers to them again on page 1671, where he has a table, and gives his conclusions in regard to the observation shown in that table.

(The conclusions referred to by the witness are as follows):

$$\text{Average error of Gurley meter} = 6/7 \times \frac{2.16}{33.21} = 5.6 \text{ per cent}$$

$$\text{Average error of Haskell meter} = 1/7 \times \frac{2.16}{33.21} = 0.93 \text{ per cent}$$

Q. What is your opinion as to the propriety of deriving an increment from the ratio of fluctuations from one lake to another, as for instance, from Erie to Lakes Michigan-Huron?

A. I could not consider it as anywhere near as accurate as the method of actually determining the discharges of the outlets.

Q. Why?

A. The factors involved are not known, or cannot be determined with anything like the accuracy with which we can make the measurements which give us our discharge.

Q. What are some of the factors that you have in mind?

A. Why, evaporation, rainfall, run-out.

Q. How about ice?

A. Ice, of course, upsets conditions in several of the lake outlets nearly every winter, so that winter conditions are entirely different from those of the open season.

Q. What effect does the ice have upon Lakes Michigan-Huron?

A. It dams up the St. Clair River and thereby holds the water, impounds it in Lakes Michigan-Huron, to the detriment of Lake Erie.

Q. And Lake Erie falls?

A. Lake Erie falls. There are plenty of cases in the gage records which show that.

Q. Does that in your opinion interfere with the ratio of fluctuations as compared with open season flow?

A. Certainly.

Q. In general, what are the ice conditions on the St. Lawrence, and what effect do they have upon Lake Ontario?

A. The ice blocks several of the channels, as you get down among the rapids, and the tendency of course is when those channels are blocked for the water to rise in Lake Ontario.

Q. What is the ice effect upon Lake Erie, with reference to the other lakes?

A. There is practically little or no ice effect on Lake Erie; that is so far as the Niagara River is concerned.

Mr. Hopkins: That is all.

Cross examination reserved.

Depositions in the above entitled cause, taken pursuant to notice, before the Commissioner, at the offices of the Sanitary District, Chicago, Illinois, beginning on Wednesday, February 25, 1914, 10:30 A. M.

Present:

Mr. Albert L. Hopkins, representing the Government.

Mr. Edmund D. Adcock, representing the Sanitary District.

EUGENE E. HASKELL resumed the stand for cross examination by Mr. Adcock and testified as follows:

Q. Since 1906, you have been Dean of the College of Civil Engineering at Cornell University, Mr. Haskell?
A. That is director of the college, my title is.
Q. Director?
A. Yes, Dean of the College Faculty.
Q. Just what does that mean? You are the head of the college, aren't you?
A. Head of the college; the representative between the college and the Board of Trustes.
Q. And prior to that time you were with the Lake Survey?
A. I was with the Lake Survey from the spring of 1893 to 1906.
Q. When you left the Lake Survey, you were Principal Assistant Engineer, were you not?
A. Yes.
Q. From what time?
A. From the spring of 1893.
Q. And your duties were similar to the duties of the present Principal Assistant Engineer?
A. Yes, sir.
Q. When was the Lake Survey proper organized?
A. You mean the present organization?
Q. Yes.
A. The old Survey closed its doors in 1882 and the Survey was re-organized in 1893.
Q. And prior to your connection with the Lake Survey, what work were you doing, Mr. Haskell?

A. For the eight years previous to my going with the Lake Survey, I was with the Coast and Geodetic Survey at Washington, D. C.

Q. How long altogether were you in the Government service?

A. In the Government service?

Q. Yes.

A. With the exception of about six months in 1880, I was with the Government service from July, 1879, up to my going with the University in 1906.

Q. What were your duties as Principal Assistant Engineer of the Lake Survey?

A. Supervising the field work, and the work of the field force.

Q. During that time, you had charge and direction of the measurements of the St. Clair, Niagara and St. Lawrence Rivers, did you not?

A. From the time that investigation started.

Q. And the measurements were made under your direction?

A. They were.

Q. Mr. Shenehon had, under you, charge of the Niagara measurements, didn't he?

A. He did.

Q. And Mr. Sabin the St. Clair measurements?

A. The St. Clair measurement.

Q. Mr. Blanchard made some measurements on the St. Marys River?

A. Yes.

Q. And also on the Detroit?

A. Yes.

Q. And Mr. Shenehon also made measurements on the St. Lawrence River?

A. Yes.

Q. You devised the method by which the measurements, the discharge measurements, should be made, did you, Mr. Haskell?

A. Substantially so.

Q. And under your instructions, the measurements were made?

A. They were.

Q. Did you have anything to do with the selection of the

gaging section or the hydraulic section where the measurements were made in the different rivers?

A. That is only in a general way, where the party was sent into the field direct from the office.

Q. Then they advised with you as to the proper place, after they had made surveys, did they?

A. Yes.

Q. Will you describe the work on the St. Clair River, the early work which was done by Mr. Sabin?

A. By Mr. Sabin?

Q. Yes.

A. Mr. Sabin was sent to Port Huron for the purpose of making an examination and locating a cross section for the discharge work of that river, and he selected a section which we have always called Dry Dock; which was near or just below the old Dunford-Alverson Dry Dock.

Q. Did Mr. Shenehon use the same methods generally in measuring the discharge of the Niagara River that were used by Mr. Sabin on the St. Clair?

Mr. Hopkins: I make a general objection to all this line of testimony as not proper cross examination.

A. Why the methods are in general similar. There may be a little difference as to carrying out the details, which are not at all vital to the success of the work.

Q. Were there more than two meters used on the St. Clair work in the co-efficient work, by Mr. Sabin?

A. You say more than two?

Q. Yes.

A. I think not, although I would not be positive of that.

Q. Where was the multiple meter set used?

A. In the Detroit River.

Q. Those measurements were made when, what year?

A. I shall have to refer to the report to definitely locate it. My recollection is that we worked there in 1901.

Q. In 1901?

A. (Referring to report.) In 1901 I find it. The discharge measurements on the Detroit River were made in 1901-1902.

Q. I call your attention to page 5369 of the Report of the Chief of Engineers for 1900, and I will ask you whether that refreshes your recollection as to whether or not a multiple meter set was used in the co-efficient work on the St. Clair River?

A. It does. It was used on the St. Clair River. The work was started there.

Q. That was the work done by Mr. Sabin?
A. That was the work done by Mr. Sabin.
Q. Was that method used on the Niagara River?
A. On the Niagara?
Q. In the work done by Mr. Shenehon?
A. No.
Q. What were your duties as director of the college of civil engineering at Cornell?
A. My duties as director?
Q. Yes.
A. They are largely executive.
Q. What do you mean by that?
A. Why I look after all matters pertaining to the college, with the President, with the Board of Trustees and with the University Treasurer; see that the schedule of work for each department of the college is properly looked after; that it has the proper and requisite teaching force.
Q. In case it has not the requisite teaching force, you see to the employment of men?
A. See to the employment; make recommendations to the President.
Q. If any member of the teaching force were not qualified, you would discharge him, would you?
A. That is arranged there; that is a full professor is appointed for life. That is a man who has been tried out and has reached such a stage of efficiency that they think he is worth while. He is appointed for life, and is not removed without cause or without he chooses to resign. An assistant professor has an appointment for five years, and he is tried for five years, and recommended finally, or tried five years more as the case may be.
Q. And he may be removed at any time during the five years for cause?
A. For cause.
Q. And I presume one of the causes would be incompetency, wouldn't it?
A. Incompetency, certainly. We have what we call the grade of instructors. They are men who are employed, with the exception of the second grade, by the year; reappointed every year. I should have said that the third grade of instructors are appointed for two years instead of one.
Q. Is the second grade of professors and instructors higher or lower grade than the first?
A. It is higher.
Q. It is a higher grade?

A. It is a higher grade, the second is.

Q. There is a meter called the Haskell Meter, I believe. I presume it gets its name from the fact that you invented the meter or designed that meter?

A. Designed that particular meter; it does.

Q. You have the A, and B, meters, haven't you?

A. Yes, and three others.

Q. And three others. The A is substantially like the B, except that it has a direction attachment?

A. Direction attachment.

Q. Which do you consider the better type of meter?

A. That is for measuring the velocity of water, there is practically no difference between them.

Q. Which was used by you in your measurements of the different rivers, the A or the B meter?

A. The B meter was used largely. The A meter was used in a number of instances. It was used from the International Bridge at Buffalo for a time, and if I remember correctly it was also used in that multiple meter set. Those were so long ago that the details—

Q. That was the A meter?

A. That was the A meter.

Q. Was the B meter used?

A. The B meter was used also. In fact that was used more than the A.

Q. You, of course, consider the Haskell meter the best meter on the market, do you, Mr. Haskell?

A. That is rather a personal question.

Q. That is it will measure accurately, perhaps more accurately than any other current meter?

A. That is the feeling I have, Mr. Adcock. I do not suppose I should have invented a meter had I not been able to find fault with the ones that went before.

Q. From your work and experience, I presume you are familiar with the generally accepted laws governing the flow of waters in closed and open channels?

A. Yes, sir.

Q. What are the factors entering into a formula for the flow in an open channel?

A. That is the velocity of the current and the area of the cross section; and the stage of the river.

Q. You mean by that the fall?

A. The fall?

Q. Yes. Does the length of the channel have anything to do with the factors in determining the flow?

A. Only in a general way.

Q. I think that you probably misunderstood my question in that your answer was as to the flow as it passed a certain section. My question was, what are the factors entering into a formula for the flow in an open channel?

A. Well, length really is of no importance.

Q. Is the fall between the ends of the section of a channel considered of any importance?

A. Why we aim to locate a cross section for discharge work, so that the two ends of it are practically of the same elevation.

Q. I am not talking about the laying out of a section for current meter measurements, but I am speaking of the factors which enter into the formula for the flow in an open channel. Isn't the area of the cross section of the channel, the length of the channel, the fall between the ends of the section of channel considered, and the co-efficient to be determined by experiment, aren't those the different factors that enter in?

A. Certainly.

Q. And the most common formula, the one commonly used is the Chezy formula, isn't it?

A. Yes, that is one of them, the most common one.

Q. What are the different terms of that formula?

A. It is so long since I have bothered with those; I seldom ever have use for the formula, so I make no effort to remember it. V equals C into the square root of R S.

Q. I presume V means velocity?

A. Velocity.

Q. C is what?

A. The co-efficient.

Q. The constant?

A. To be determined by experiment.

Q. And the R is the hydraulic radius?

A. R is the hydraulic radius and S the slope.

Q. S is the slope?

A. Yes.

Q. Has C been determined, the value of C?

A. It has been determined by a number of experimenters in the past.

Q. How does the value of C change, does it change for different velocities in the same channel?

A. I believe so.

Q. Suppose the velocity should be changed, say 10 per cent, how much change would you expect in the value of C in this formula?

A. Will you ask that again, Mr. Adcock?
Q. (Question read.)
A. Really that is—
Mr. Hopkins: Objected to as not proper cross examination.
The Witness: It is a line in hydraulics that I have not been into in years, so to speak.
Q. (Question re-read.) In the same channel?
A. It would be a very small change indeed.
Q. What in general causes water to flow in a channel?
A. Gravity.
Q. That is the fall?
A. The fall, yes.
Q. In the Detroit River the flow is caused by the excess elevation of Lake St. Clair above that of Lake Erie, is it not?
A. It is.
Q. And if Lake Erie should rise to the same level as Lake St. Clair and remain level with Lake St. Clair as the latter changed, there would be no flow through the Detroit River. That is true, isn't it?
A. If Lake Erie—
Q. If Lake Erie should rise to the same level as Lake St. Clair and remain that way, then there would be no flow through the Detroit River?
A. The discharge of the St. Clair River would have to go somewhere. If Lake Erie were to fill up to the level of Lake St. Clair, of course, it would mean that the St. Clair River was emptying directly into a lake at the elevation of Lake St. Clair.
Q. And at least for a time, there would be no flow in the Detroit River?
A. For a time.
Q. And your proposition is that in time Lake St. Clair's flow, or the flow of the St. Clair River rather would raise Lake St. Clair, so that there would be a difference in the elevation of St. Clair and Erie, and thus there would be a flow through the Detroit River. Is that correct?
A. Yes.
Q. And there are no elements that produce flow in a channel other than the head or fall?
A. Are you speaking with regard to fresh water streams?
Q. Yes.
A. Certainly that is the case. It is not true with tidal streams, however.

Q. What is a sharp-edged weir, as distinguished from other weirs?

A. It is where the crest is narrow and worked off to a sharp edge.

Q. How is the discharge of such a weir obtained?

A. By the head of the weir.

Q. Who have made the principal investigations on the flow of water over such weirs?

A. The late James P. Francis made very extensive observations on the flow of water over weirs; also Fteley and Stearns, and Bazin.

Q. They derived formulæ for the flow, did they not, over such weirs?

A. They did.

Q. What is the most commonly accepted form of weir formula?

A. I should say that of Francis.

Q. What is that formula, do you remember it?

A. I could not give it. It has been so long since I have been testing with these problems as referred to weirs.

Q. Is it Q equals C L H, exponent 3 over 2?

A. It is very close to it. That is the formula.

Q. In that formula Q equals the discharge?

A. Yes.

Q. The length of the weir crest?

A. Yes.

Q. H equals what?

A. The head of the weir.

Q. The head of the water above the crest?

A. Yes.

Q. And the C equals the co-efficient determined by experiment?

A. Determined by experiment.

Q. How was C determined, the co-efficient?

A. By actually determining the volume that flowed over a weir for various stages?

Q. That is volumetrically?

A. Volumetrically.

Q. From Mr. Francis' experiments, what value of C was adopted for general use?

A. I have forgotten the value.

Q. Was it 3.33?

A. 3.33, something like that.

Q. Still speaking of a sharp edge crested weir?

A. Yes.

Q. That is your understanding?

A. Yes.

Q. Did the value of C in Mr. Francis' experiments change with the different weirs used by him?

A. I should say yes, although it is a long time since I have read those experiments. I do not recall the details of them.

Q. Do you know through what range as a mean for each type?

A. It seems to me it was about 1.6 feet.

Q. Through what range as a mean for each type; that is the co-effiicent change?

A. Well, I have forgotten. It would be mere guess work on my part to make any statement in regard to it at this time.

Q. Do you remember through what range the head changed?

Mr. Hopkins: You are still speaking of Francis' experiments?

Mr. Adcock: Yes.

Mr. Hopkins: Objected to on the ground he is not qualified to testify as to what the other man did.

Mr. Adcock I assume that these are well known experiments. The calibration of a certain weir was criticised by Mr. Haskell, in the course of his direct examination.

A. I have forgotten the details of those observations. My general impression is that it was somewhere around two feet, the range of head on the weir which Francis used.

Q. I will refer you to page 122 of Lowell's Hydraulic Experiments, and ask you if that will refresh your recollection; the author being—

A. Mr. Francis.

Q. Mr. Francis?

A. Yes, James P. Francis.

Q. I will ask you to refresh your recollection by examination of that. Also refer to the pages following (handing witness volume referred to).

A. 1.56 feet seems to be the maximum given here.

Mr. Hopkins: Let it appear that you are reading from the book just handed to you, Mr. Haskell.

The Witness: Yes.

Mr. Adcock: I do not think it need appear that way at all. I have asked the witness a question as to what it was, and I have given him a book to refresh his recollection.

Mr. Hopkins: Is your answer based upon your knowledge independently of the book or is it what you read from the book, Mr. Haskell?

A. It is what I read from the book.

Mr. Adcock: Q. Is this work of Mr. Francis considered an authority by hydraulic engineers?

A. It is.

Q. One of the standard works?

A. One of the standard works.

Q. Through what range did the co-efficient vary by individual experiments in Mr. Francis' work? You still have Mr. Francis' work there, have you not?

A. I have.

Q. You can refer to it if you wish to refresh your recollection.

Mr. Hopkins: To all questions based upon the book, if it does refresh your recollection so that you can testify from that recollection, say so; if not, say you are reading from the book.

A. The range here is from 3.36 to 3.31, that is the co-efficient.

Mr. Adcock: Q. What page are you referring to, Mr. Haskell?

A. Page 123.

Q. That was for the groups that you stated, was it not?

A. I take it that that is—

Q. The group means?

A. No; they are in the right hand column, the group means—yes, that would be true.

Q. For group means?

A. For group means, it would be true.

Q. For individual experiments?

A. I did not catch that last question.

Q. What was the range of co-efficient by individual experiment?

A. I find 3.3 to 3.36.

Q. What percentage would this be each way from a mean value of 3.33? It would be about .9 of 1 per cent, would it not?

A. I should say so.

Q. The Mr. Stearns that you referred to as collaborating with Mr. Fteley was Mr. Frederic P. Stearns?

A. Frederic P. Stearns.

Q. In the experiments of Fteley and Stearns on the Farm Pond Gate House Weir, what were the dimensions of the weir used?

A. I don't remember them.

Q. These experiments are recognized as authoritative experiments among hydraulic engineers, are they not?

A. They are recognized as good experiments.

Q. For the purpose of refreshing your recollection, I will refer you to Transactions of American Society of Civil Engineers, Volume 12, page 69, and ask you if you can give us the answer to that question after making reference to the book and page mentioned?

Mr. Hopkins: I think I will make an objection to this testimony as to experiments by other people, not cross examination, not competent; and I want it to appear whether the witness is testifying from his own recollection or from certain books that are handed to him.

Mr. Adcock: Q. You knew what those experiments were at one time, did you not, Mr. Haskell?

A. Yes, I have been familiar with them. I have read these experiments over, sometime ago, and was familiar with them at that time. I have not had occasion to use them for several years and so have forgotten many of the fine points that are given here.

Mr. Adcock: Does the counsel for complainant wish to protest further?

Mr. Hopkins: Just simply as to the form of your question. You say refresh his recollection. When he is simply reading from a book, he is not refreshing his recollection.

Mr. Adcock: Then you do not wish to protest further?

Mr. Hopkins: I will take care of that when we get to it. I am simply making these objections now so that you may know what I have in mind as to form. Anything else I have to say as to substance, we can take up later, anyway.

Mr. Adcock: I considered that your objection perhaps was more to the substance.

The Witness: Will you ask that question again, Mr. Adcock?

Mr. Adcock: Q. In the experiments of Fteley and Stearns on the Farm Pond Gage House Weir, what were the dimensions of the weir used?

A. The length of the weir is given as 18.966 feet.

Q. And the height of the weir?

A. Depth of channel below crest of weir was 6.55 feet.

Q. This weir was considerably larger than the weir used by Mr. Francis?

A. I believe so.

Q. Do you recall the dimensions of Mr. Francis' weir?

A. No, I do not.

Q. It is your belief that it was larger, is it not?

A. Yes, it is.

Q. What was the range of C in the formula Q equals C L H, exponent 3 over 2, and how many experiments are included in the Fteley-Stearns derivation?

A. Ten experiments are given in this table, the lowest value of C being 3.304, and the highest 3.327, practically.

Q. Isn't the range from 3.29112 to 3.3040 for ten experiments?

A. It is for the ten experiments.

Q. The percentage variation from the mean value of say 3.2976 was less than .2 of 1 per cent, was it not?

A. It was.

Q. What was the range of discharge measured, was it from 20 c. f. s. to 130 c. f. s.?

A. It was, according to this table.

Q. Referring to the Large Basin experiments with a weir approximately five feet long and 3.17 feet high, what was the range of C, in the formula mentioned, excluding 3 defective experiments?

Mr. Hopkins: Have you referred to the Basin experiments before?

Mr. Adcock: That is another weir.

Mr. Hopkins: Describe it in detail. Tell us in your answer what you are referring to and where you got your information.

A. That is in Table 14, opposite page 56.

Mr. Adcock : Q. These were the experiments of Fteley and Stearns, were they?

A. Yes. The largest one which I see given here is 3.428 and the smallest one is 3.340.

Q. You are referring to page 56, are you?

A. To the table opposite page 56, Large Basin Experiments.

Q. That is showing the Fteley-Stearns experiments as published in the Transactions of the American Society of Civil Engineers?

A. Yes.

Q. How many experiments do these cover?

A. Sixteen are recorded here.

Q. There were three defective experiments excluded, were there not, and the range which you have just mentioned there covered 13 measurements or experiments, did it not?

A. There are three observations in that—

Q. So that the range covered 13 experiments?

A. The range covered 13 experiments, rejecting those three; 16 altogether, 3 of which were rejected.

Q. What was the range of discharge?

A. Not counting the rejected experiments, 2.078 to 12.750 cubic feet per second.

Q. What was the maximum percentage error from the mean value of the co-efficient of say 3.384?

A. Less than 1 per cent.

Q. Now, Mr. Bazin made some experiments, didn't he?

A. Yes.

Q. He was a Frenchman?

A. He was a Frenchman.

Q. And they are recognized as authority among hydraulic engineers, are they not?

A. They are, for the types of weirs upon which he experimented.

Q. What dimensions of weir did Mr. Bazin use?

Mr. Hopkins: Same objection to questions in regard to his experiments as was made to the others.

Mr. Adcock: Those experiments of Mr. Bazin are familiar to you, are they not?

A. Why I have read them, but it has been several years since and I am not familiar with the details.

Q. You recognize those experiments as authority, don't you, for the type of weir used?

A. Upon the type of weir upon which he experimented, they are considered as authority.

Q. He made experiments with a sharp edged weir, or sharp crested weir?

A. Yes, he made experiments on a large number of types. I do not recall the individual ones.

Q. I have handed you a book. What is it called?

A. Number 52 of the Annals des Ponts et Chaussees. The paper is entitled: "Experiences Nouvelles Sur L' Ecoulement en Deversoir, Par M. H. Bazin, Inspecteur General des Ponts et Chaussees."

Mr. Adcock: With your permission, perhaps Mr. Williams can assist the witness, as I understand he is familiar with the French language.

Mr. Williams: I think Mr. Haskell has all the information necessary for him to proceed.

Mr. Hopkins: Let it appear that Mr. Williams is telling what is in that book.

Mr. Adcock: Q. What dimensions of weir did Mr. Bazin use?

A. He evidently started with a weir two meters in length.
Q. What was the size of the weir that he later used?
A. Observations are shown here in the table labeled "Series Number 2," in which he used a weir one meter in length.
Q. What was the height of the different weirs?
A. The height of the weir is given as 1.135 meters above the bottom of the channel.
Q. How many experiments did he make on the largest weir, was it 67?
A. 67.
Q. What was the range of his co-efficients?
A. The first one seems to be the largest. His co-efficient ranged from 0.4225 to 0.4440.
Q. What is the maximum percentage variation from a mean value of say 0.4332?
A. About 1 per cent.
Q. Less than .2 of 1 per cent, wouldn't it be?
A. Yes, less than .2 of 1 per cent.
Q. Assuming a weir constructed in all particulars like the 19 foot weir of Fteley and Stearns, how accurately would you think it possible to determine the discharge of water over it by using as a basis the experiments of Fteley and Stearns on their 19 foot weir?
Mr. Hopkins: Objected to as not proper cross examination.
A. There are other qualifications to come in there.
Mr. Adcock: Q. What is that?
A. There are other qualifications.
Q. What are they?
A. That is the weirs should be identical.
Q. That they should be identical. In all particulars alike?
A. Yes, all particulars alike.
Q. You mean of exactly the same size or what?
A. Not necessarily the same size but—
Q. Similar in dimensions?
A. Similar in dimensions and similar in construction.
Q. Assuming that they were in all particulars the same?
A. I should say within 1 per cent.
Q. Would it be less than 1 per cent?
A. Not much less.
Q. Wouldn't it be approximately a quarter of 1 per cent?
A. It would depend entirely on the amount of labor that you put on the observations, as to whether it would be that accurate or not.
Q. Assume that Fteley and Stearns got their co-efficients

to agree within .2 of 1 per cent, what would you say then as to the accuracy of measuring water under the conditions mentioned, measuring the discharge under the conditions mentioned?

A. For that particular weir, I should say within that percentage.

Q. Assuming the weir to be 6.65 feet instead of 6.55 feet in height, what difference would that make?

A. Practically no difference.

Q. Assuming a length of 16 feet instead of 19 feet, would the discharges be proportional to the length?

A. Yes.

Q. What other forms of weirs are there?

A. Flat crested, round crested; in fact, a large variety of forms.

Q. Is the same formula applicable to other types if the coefficient be changed?

A. Yes.

Q. Can any obstruction in a stream of flowing water, such that the level of water on the downstream side is below the level of the top of the obstruction when water is flowing over it, be considered as a weir?

A. Yes.

Q. Does the discharge of all overfall weirs vary as the 3-2 power of height above the crest of the surface of still water upstream?

A. Substantially so.

Q. You are familiar with the St. Marys River at Sault Ste. Marie, are you not?

A. Yes.

Q. You made some discharge measurements there?

A. I did.

Q. And they were carefully and accurately made?

A. They were.

Q. You are familiar with the discharge observations made in 1896 at the Spry Dock Section?

A. I am.

Q. They were made by you?

A. They were. That is the winter of 1895-1896, those were made by me.

Q. You are also familiar with the discharge measurements on the St. Marys River at the International Bridge about 1902?

A. I am.

Q. They were made by Mr. W. E. Wilson?

A. He made the observations, I believe, at that time. There were some made previous to his by Mr. Russell; also by Mr. Johnson.

Q. You have already stated that you are familiar with the discharge measurements made on the St. Lawrence and Niagara Rivers by Dean Shenehon, haven't you?

A. I have.

Q. Are you familiar with the measurements made on the St. Marys River at Section Brewery in 1905?

A. I am.

Q. They were made by whom?

A. Mr. Murray Blanchard had charge of the party.

Q. Who else?

A. No one else.

Q. Was Mr. Turner, Professor K. B. Turner, in the party?

A. Mr. Turner acted as recorder in the party.

Q. Do you know whether he did anything else beside acting as recorder?

A. Why that is all he was supposed to do. His duty was that of a recorder to that party.

Q. You sent him up there as a recorder?

A. As a recorder to that party.

Q. Do you believe the measurements on the St. Marys River to be more or less accurate than those on the St. Lawrence and Niagara?

A. They are less accurate than those on the Niagara.

Q. What percentage?

A. From 2 to 3 per cent, I should say.

Q. The measurements made on the St. Clair River in 1899, 1900, 1901 and 1902, were made by Mr. Sabin and Mr. Blanchard, under your direction, were they not?

A. They were.

Q. What is your opinion as to the correctness of the discharges obtained from those measurements on the St. Clair, as compared with those on the Niagara and the St. Lawrence by Professor Shenehon, under your direction?

A. I should give the individual measurements equal weight. That is, I should consider those made on the St. Clair just as accurate as on the Niagara.

Q. What about the measurements on the Detroit River as to their relative accuracy?

A. The individual measurements, I should place nearly the same precision on them.

Q. Mr. Quintus made some measurements on the Niagara River, did he not?

A. He did.
Q. He was an assistant engineer in the United States Engineers' Office at Buffalo.
A. At Buffalo.
Q. The results of his measurements are published in the report of the Chief of Engineers for 1893, part 6, page 4371, are they not?
A. I think that is correct. It was about that time.
Q. Just when and where were those measurements made, do you remember?
A. As I recall it, they were made just below the International Bridge.
Q. How far?
A. As I recall it, very close to what we have called the Open Section.
Q. About 1,800 feet below the International Bridge?
A. About 1800 feet below the International Bridge.
Q. That was near Mr. Shenehon's section?
A. Near Mr. Shenehon's section.
Q. Is there on file a cross section of the river, showing the soundings he took?
A. I have forgotten whether it is in his report or not.
Q. What increment did Quintas get for the Niagara River?
A. An absurd one.
Q. What is that?
A. An absurd one.
Q. Was it 21,000?
A. I have forgotten his figures. When I said an absurd one, I was referring more particularly to the form of the curve, the discharge curve which he worked out.
Q. When did he make his measurements?
A. It was somewhere in the early nineties. I have forgotten the exact year.
Q. About 1893, was it?
A. Somewhere about that time. It was some two or three years previous to the beginning of the investigation of lake levels by the Lake Survey.
Q. Mr. Quintas was not connected with the Lake Survey?
A. No, he was an assistant engineer in the United States Engineers' office at Buffalo.
Q. What was the matter with his curve?
A. The trend of it was in the wrong direction.
Q. What kind of a meter did he use?
A. He used a cup wheel meter, known as the Price Meter.

Q. You would not give much weight to Mr. Quintas' measurements then?

A. No, I should not. They gave approximate results.

Q. How about his increment?

A. I should not give much weight to that.

Q. Have you any idea as to the percentage of accuracy of Quintas' increment and discharge measurements?

A. I should not care to express any idea.

Q. Didn't he make his soundings right, or accurately?

A. My recollection of that matter is that those observations were very hurried, and the methods followed throughout were crude as compared with those under which the Lake Survey observations were made.

Q. He got his cross section, didn't he?

A. Oh, certainly.

Q. And then he had gage readings, didn't he, showing the water levels at the times?

A. Certainly.

Q. And he measured the velocity of the current?

A. Yes, and as I recall—

Q. At the hydraulic section?

A. And as I recall it, without anchoring their boat from which they worked. The boat ran her wheel to keep up on the range, while the observations were in progress.

Q. And you think that the meter was not immersed exactly on the section, on account of not anchoring the boat?

A. It might not have been.

Q. And that would make considerable difference?

A. There is a chance for error to come in, from the operation of the wheel of the tug.

Q. That is the tug churning her wheel there would create a disturbance which might throw the meter off?

A. That is it might influence the meter.

Q. How far away was the tug wheel from the place where the meter was submerged?

A. Oh, I don't recall the details of that work.

Q. Do you remember approximately?

A. Why it was customary on the Mississippi River, where Mr. Quintas worked on discharge work for some time, to lower the meter about 12 feet from the side of the boat, and the exact distance on these particular observations I do not recall; don't know that I have ever known that.

Q. From the middle of the stern or the bow of the boat?

A. It was customary to work from the stern of the boat with the meter.

Q. You think that any eddying which might be caused by the churning of the wheel of the boat, or from any other cause, would have some effect on the meter, then?

A. On velocities measured at the surface or near the surface.

Q. At what point was the meter placed in the water with reference to the water surface, the depth?

A. I don't remember, but I think he used mid depth.

Q. Instead of .4?

A. Instead of .4.

Q. Was the mid depth used in the work on the St. Clair River by Mr. Sabin?

A. I believe Mr. Sabin did use mid depth.

Q. Suppose that we had an open channel similar to the St. Lawrence or the lower Mississippi River, and at a certain period the fall over a certain length was 5 feet, and suppose that at some other time the fall was still 5 feet, but the water was, say, 1 foot lower at both ends, about what would be the effect upon the discharge in the second case, as compared with the first?

A. It would be less.

Q. How much less, what ratio?

A. That depends entirely on the size of the stream at that particular point.

Q. Would it be in proportion to the mean cross section?

A. In proportion to the cross section and velocity.

Q. (Question read.)

A. It would be less, the discharge would be less.

Q. In what proportion would it be less?

A. In proportion to the cross sections.

Q. Would there be a further decrease due to decrease in hydraulic radius?

A. A further decrease?

Q. Yes?

A. (Answer deferred until after recess.)

Recess to 2:20 p. m.

After Recess, 2:20 p. m.

EUGENE E. HASKELL resumed the stand and testified further on cross-examination as follows:

Q. (Question read as follows: "Would there be a further decrease due to decrease in hydraulic radius?")

A. Yes.

Q. Suppose in the same channel at another time the fall was only 4.5 feet and the elevation of the water at the upstream end was still 1 foot lower than in the first case, how would the discharge compare with that of the original condition, that is would it be more nearly equal to it than in the last case considered or otherwise?

A. That is the discharge would be less.

Q. Discharge would be less?

A. Yes.

Q. What is your opinion as to the run-off from the drainage areas of the Great Lakes and the precipitation on their surfaces, as to whether the total amount of inflow from all sources is increasing or decreasing?

A. I do not believe we have any reason to believe that it is any less than it used to be.

Q. Is it any greater?

A. Why we have no reason to think that it is any greater. That is, I am speaking now of a long period of time. Of course there are annual variations.

Q. But you consider it to be about the same in the later period as in the former periods?

A. Yes, that is the mean.

Q. Taking it over a long period?

A. Taking it over a long period, yes.

Q. Is it your opinion that the inflow into Lakes Michigan and Huron has been greater or less during the last 20 years than it was during the period from 1860 to 1880?

Mr. Hopkins: Objected to as not proper cross-examination.

Mr. Adcock: Is it your objection that it is not within the scope of the direct examination of the witness?

Mr. Hopkins: Yes. I did not go into anything of that kind.

A. I should say there were periods in that last 20 years when it was less.

Q. But take the average, the mean for the last 20 years as

compared with the average, the mean for the period from 1860 to 1880.

A. From 1860 to 1880—

Mr. Hopkins: Did this involve the run-off?

Mr. Adcock: I presume it would; it is inflow into the lake.

Mr. Hopkins: It was not precipitation alone?

Mr. Adcock: No.

The Witness: I should state that they were substantially the same.

Q. If you had two reservoirs of different size with their water surfaces at certain elevations with a certain inflow and outflow, and for a given time the flow into both should be increased an equal amount, assuming that both had discharge openings exactly similar as to discharging capacity for equal changes of head, would you expect the water to rise by a greater amount in one than in the other?

A. Yes.

Q. Which one?

A. In the smaller one.

Q. On account of the difference in storage?

A. Not necessarily that, the difference in evaporation.

Q. Would the storage have no effect?

A. Certainly, that is if an equal quantity were flowing into both lakes.

Q. And one was greater than the other?

A. Certainly.

Q. The water would rise higher in the smaller lake?

A. In the smaller lake.

Q. Than it would in the larger one?

A. Yes.

Q. And one reason would be because of the difference in the storage capacity?

A. Yes.

Q. And you say that another reason would be because of the difference in evaporation?

A. That is that might be the case.

Q. It might be the case?

A. It might be.

Q. That would depend, I presume, upon conditions?

A. Depend upon conditions.

Q. If the inflow to the smaller were greater in the same given time than that to the larger and the water in the two reservoirs raised by the same amount, what would that indicate as to the relative outflow per unit change of height of the two outlets?

A. I have not got that question clear in my mind yet.

Q. (Question read.)

A. If I understand the question correctly, I should say that the increment in the larger reservoir, the increment from the outflow in the larger reservoir would be the greater.

Q. (Question re-read.)

A. It would be greater in the smaller reservoir.

Q. Is the increment of the Detroit River greater or less than that of the St. Clair?

A. It is greater.

Q. Upon what do you base your conclusions stated in the last answer?

A. By virtue of the additional supply which comes in between Lake Huron and the Detroit River.

Q. That is over the St. Clair River?

A. The St. Clair River Basin, or the Lake St. Clair and St. Clair River Basin.

Q. Would that same conclusion be applicable, a comparison between the Niagara and the Detroit Rivers and between the Niagara and St. Lawrence Rivers?

A. Not necessarily so.

Q. Will you state your reasons, Mr. Haskell?

A. For certain seasons of the year, it would, and for other seasons of the year, when the evaporation was greater, I should say it would not be so.

Q. What seasons of the year?

A. The summer months.

Q. That is it would not hold in the summer months, that is your conclusion?

A. Yes.

Q. Do you believe that an increment can be derived for the St. Clair River that will be applicable to the varying conditions of the period from say 1884 to 1908, from the observations made from 1899 to 1908, inclusive?

A. I do.

Q. Can an accurate increment be derived from those observations without involving in the equation of discharge, the position of Lake St. Clair?

A. Yes, I believe one could be worked out.

Q. If you had a reservoir into which a quantity of water was flowing at the same time that water was flowing out, and the water was rising in the reservoir at a known rate, and a change should be made in the outlet such as to cause a less rapid rise in the reservoir, what would that indicate as to whether the outlet had been enlarged or restricted?

A. If I understood that correctly, it would indicate an enlargement of the outlet.

Q. If the inflow and outflow continued under the last condition until the water in the reservoir ceased to rise, would it have reached a higher or a lower level than in the case no change had been made in the outlet?

A. It would have reached a lower level.

Q. And if when the outlet was changed its area had been decreased, would the water then rise more or less rapidly in the reservoir, the inflow remaining the same?

A. It would have a tendency to rise.

Q. It would rise more rapidly, wouldn't it?

A. It would rise more rapidly.

Q. I hand you here, Mr. Haskell, a paper which I ask to be marked Haskell's Exhibit A, for Identification, February 25th, upon which there appears certain figures in columns I, II, III, IV, V, and VI, and ask you to examine it, and suppose that for a certain channel similar in magnitude to those connecting the Great Lakes, but without such rapids or falls as occur at the Soo and Niagara, for a period of years the elevation of the water at the upstream end had been as shown in the first column, and the fall through the channel had been as shown in the second column? And suppose that it were desired to obtain a discharge curve for this section that would represent the discharges of the period referred to the head at the upstream end, and suppose that there had been made a series of 27 observations under the conditions of columns III and IV, and that there was also available a series of 23 observations made with equal care under the conditions shown in column V and VI, which in your judgment would give a discharge curve the more closely applicable to the assumed conditions of columns I and II; columns I, III and V, representing the elevations and columns II, IV and VI, representing slope?

Assuming further that the elevations shown are at the head of the river.

(Table handed to witness in connection with the foregoing question was marked Haskell's Exhibit A, February 25, 1914, and is as follows):

I	II	III	IV	V	VI
247.77	6.46	245.66	6.27	245.84	5.95
247.55	6.10	245.48	6.00	245.57	5.79
245.30	6.03	245.85	5.95	245.51	5.70
247.04	6.00	245.19	5.92	245.71	5.67
246.50	6.00	245.57	5.79	245.63	5.67
247.35	5.87	245.51	5.70	245.28	5.60
245.88	5.79	245.71	5.67	245.20	5.58
245.62	5.59	245.63	5.67	245.24	5.56
245.50	5.59	245.28	5.60	245.00	5.56
245.72	5.56	245.20	5.58	245.45	5.55
245.72	5.21	245.24	5.56	245.38	5.55
245.16	5.50	245.00	5.56	245.15	5.54
244.42	5.47	245.45	5.55	245.11	5.51
245.07	5.42	245.38	5.55	245.32	5.46
245.74	5.42	245.15	5.54	245.07	5.43
245.81	5.35	245.11	5.51	244.96	5.38
244.96	5.33	245.32	5.46	244.84	5.34
244.93	5.30	245.07	5.43	244.65	5.34
246.71	5.28	244.96	5.38	244.91	5.32
244.89	5.23	244.84	5.34	244.77	5.29
245.09	5.23	244.65	5.34	245.09	5.25
245.01	5.23	244.91	5.32	244.43	5.19
245.09	5.12	244.77	5.29	244.67	5.06
244.19	5.08	245.09	5.25	......	....
......	....	244.43	5.19	......	....
......	....	244.67	5.06	......	....
......	....	245.38	4.97	......	....
Aver.					
245.71	5.548	245.20	5.54	245.16	5.49
Max.					
247.77	6.46	245.85	6.27	245.85	5.95
Min.					
244.19	5.08	244.43	4.97	244.43	5.06
Change of Fall.					
......	1.38	......	1.30	......	.89
Change of Elev.					
......	3.58	1.42	....	1.42	....

A. I understand all of these gage readings were taken at the head of the river?

Q. Yes.

(Question read.)

Mr. Hopkins: I object to that question on the ground that it assumes theoretical conditions which do not appear in evidence in the case, both in regard to the presence or absence of the falls and rapids, and in regard to the channels assumed, elevations and so on.

A. I must say that I do not understand the question here.

Q. (Question read.)

A. We would undoubtedly get a more consistent result by using the slope.

Mr. Adcock: That is not the question.

(Question repeated.)

A. An engineer would naturally take that second group, the third and fourth and fifth and sixth, where he had the slope.

Q. Columns three and four?

A. Because he had the slope there.

Q. You have the slope in both cases?

A. Yes.

Q. Which would you take, three and four?

A. I should take three and four.

Q. If the elevations in columns I, III and V should have been 200 or 300 or 400 or any number of feet higher in every case, would your answer be the same?

A. Certainly; that would make no difference.

Q. Suppose that at two sections of a large river separated by say 5,000 feet, a series of discharge measurements covering at least 50 different discharges at each section should be made, in the usual manner and with the care that you use in the United States Lake Survey, including all preliminary work, and the range of head should be identical at both sections, but the observations at the two sections should be made on different days, and suppose that the mean elevation at which the observations were taken at each section were the same, and suppose that the mean measured discharges at the two sections agreed within 1 per cent, with what degree of accuracy would you say the discharge had been measured, for the center of gravity of the observations?

A. Within 1 per cent.

Q. Suppose that in a certain channel there were two weirs within 400 feet of each other, that the weirs were of different heights but of approximately the same length of crest, and assume that all the water which passed over one must pass over the other, except a small leakage which was collected and

measured and found to be less than one-tenth of one per cent of the quantity of water flowing, and assume that the quantities of water discharged over the two weirs in a series of at least 100 observations on each, when computed for the two weirs by any of the three principal weir formulae agreed within 1 per cent for each observation, the heads ranging from 1 to 3 feet, what would you say as to the accuracy of the measurements?

A. I should say they were very accurate.

Q. Within what percentage of accuracy?

A. Under those suppositions, considerably less than 1 per cent.

Q. What would you say as to the accuracy of the calibration of the weirs for the range in question if one weir was within 1-10th of a foot of the same height and within 3 feet of the same length as, and was similarly constructed to, the large weir used by Fteley and Stearns in their volumetric calibrations on the Boston Aqueduct?

A. I should say it was very accurate.

Q. Within what per cent?

A. Within less than 1 per cent.

Q. What would you say as to the accuracy of calibration if the agreement as before were within ½ of 1 per cent?

A. That it would be accurate within ½ of 1 per cent.

Q. In the float observations in Vinyard Sound, which you mentioned in your direct testimony, was the velocity uniform in the upper five feet of the current?

A. Yes, sir.

Q. Then why was the meter immersed 5 feet in that case?

A. No particular reason; it could have been two feet or three feet.

Q. How was the velocity of the submerged float observed?

A. Of the submerged float?

Q. Yes.

A. The submerged float was connected to a small copper float on the surface by a piece of fine wire and the velocity of the copper float was observed.

Q. Was the velocity of the lower float accelerated or retarded by the surface float?

A. No.

Q. How was it known that the sub-surface float remained at a uniform depth of 5 feet?

A. The sub-surface float was made of such a weight that it would partially sink the surface float, keep it in position.

Q. How do you know that the velocity was uniform in the upper 5 feet?

A. The sub-surface float was made of such a weight that it would partially sink the surface float, keep it in position.

Q. How do you know that the velocity was uniform in the upper 5 feet?

A. My recollection is that we measured the velocity at several depths from the surface down.

Q. How many?

A. I would not attempt to state that accurately.

Q. Did you measure it at the surface?

A. At the surface, and usually over five feet.

Q. How close to the surface?

A. For surface velocity when the water is perfectly smooth, the meter is usually run at one foot depth.

Q. Do you know what the velocity was at the surface, the actual surface of the water?

A. It is substantially that given in that pamphlet.

Q. How did you determine that?

A. In a tidal stream where the water is deep the vertical velocity curve is practically a straight line for considerable depth.

Q. Is it a straight line in the upper six inches of the surface?

A. If there is no wind blowing, it would be.

Q. What was the condition on that day, was there no wind?

A. Perfectly calm.

Q. The water surface was perfectly smooth?

A. Perfectly smooth.

Q. Is there no retardation due to the air when there is no wind blowing?

A. In a case of that kind it would be so small that we could not measure it.

Q. How do you know that, Mr. Haskell?

A. From experience.

Q. Would you be willing to state what experiments you have made in that connection?

A. Made a good many observations in the Gulf Stream, in the winter of 1890-91 that would confirm that.

Q. What were those observations and how were they made?

A. They were made with a current meter from the Coast and Geodetic Steamer Blake in the Gulf Stream off the coast of Florida.

Q. How close to the surface was the meter read?

A. Some days it would be run as close as a foot; and some

days not as close as that, depending upon the surface conditions.

Q. What did you make as to the distribution of velocities in the upper foot?

A. In the upper foot we practically—we did not measure anything in the upper foot.

Q. Then if that is true, Mr. Haskell, how can you say that the velocity did not change in the upper foot?

A. That is the projection of the curve, from having measured velocities below, that would have a tendency to show that there was practically no difference in that other foot.

Q. You simply projected the curve?

A. We projected the curve.

Q. You projected the curve from measurements made below the foot?

A. Yes.

Q. Below the upper foot?

A. Yes.

Q. Assuming that there was a difference in the velocity at the surface, and it was a perfectly still day, would the velocity at the surface be greater or less than the velocity at the five-foot depth?

A. Theoretically—the velocity at the surface you are referring to?

Q. Yes.

A. Theoretically it would be less because of the friction of the atmosphere.

Q. And if it were less, then the indication of the float velocity would be too small, would it not? If it were less, the indication of the velocity by the float would be too small?

A. Theoretically.

Q. Therefore if the float velocity were too low and the meter agreed with the float, the meter would under register, wouldn't it?

A. In that case.

Q. You mentioned a comparison of a meter and a weir made at Philadelphia. How accurately do you think that weir was rated?

A. That I can't say further than the work was done by engineers of the Bureau of Surveys of the city.

Q. You don't know how the weir was constructed?

A. Nothing further than what is given in a report which they made upon the subject.

Q. Did you have any experience and training in the meas-

urement of streams before entering the employ of the United States?

A. No.

Q. At how frequent intervals in the vertical are current meter measurements taken in the so-called co-efficient work?

A. Velocity measurements are made at the tenths of depth.

Q. Suppose a vertical to be so measured ten times at the same elevation of water surface, how closely would the river velocity at that vertical be determined?

A. Within ½ of 1 per cent.

Q. Suppose one-fifth depths had been observed instead of one-tenth depths, would the determinations have been more or less accurate?

A. I should say less accurate; that is as a general answer to that question.

Q. What percentage of less accuracy?

A. Oh, less than 1 per cent.

Q. Suppose that 1-20th depths were used, would the determination have been more or less accurate?

A. A general answer to that question would be that it would be more accurate.

Q. What would be the percentage of accuracy?

A. Oh, the vertical curve would be determined within less than ½ of 1 per cent, that is the true vertical curve.

Q. That is it would be more accurate than if the observations were taken at the 1-10th depth, is that right?

A. Generally speaking that would be the case.

Q. Would you say about 1-16th of a per cent?

Mr. Hopkins: Does that assume the same number of traverses?

Mr. Adcock: Yes.

A. I take it for granted you were referring to the same number of measurements of the curve.

Q. Would you say 1-16th of 1 per cent?

A. Oh, say within a quarter.

Q. Then with reference to the observation taken at the 1-10th depth, you think it would be less than ½ of 1 per cent?

A. Yes.

Q. What would you say as to that, within say 5-16ths of 1 per cent of accuracy, or ⅞ths of a per cent?

A. Why I should say that we knew the curve with an accuracy of less than ½ of 1 per cent.

Q. Couldn't you get closer than ½ of 1 per cent? That is quite a ways off?

A. Individual results might turn out less than that. You

might have certain curves where it gave less than ½ of 1 per cent

Q. I presume it is assumed that the velocity measurements were made with the Haskell meter when you give those values. Is that correct, Mr. Haskell?

A. Any good reliable meter, Mr. Adcock, will give you the same results.

Q. But you would prefer the Haskell meter, if you were going to get down as close as ½ of 1 per cent?

A. Certainly I should.

Q. Have you ever made observations using the 1-20th depths?

A. I have not.

Q. Have you ever calibrated a weir?

A. Never have had any occasion to.

Q. Have you ever used a weir in measuring water?

A. I don't believe that I have.

Q. You would prefer the Haskell meter to the weir? That is to measure the water?

A. For measuring such streams as the lake outlets.

Q. Have you ever compared a discharge measured by current meter with the same discharge determined by volumetric or gravimetric measurement?

A. No, I have not.

Q. Do you know of anyone who has?

A. No, I do not.

Q. Have you ever compared the discharge measured by current meter with the same discharge determined by an orifice, nozzle or weir?

A. No, I have not.

Q. If in determining the mean velocity in a certain vertical, two series of measurements were made, in each of which the velocities from surface to bottom were observed ten times, and in one series they were observed at the 1-10th depths and in the other at the 1-20th depths, which series in your opinion would give the more accurate determination of the ratio between the mean velocity in that vertical and the velocity at the 4-10ths depth point?

A. The greater number of observations you can have in determination of the vertical curve, the more accurately it is determined, generally speaking.

Q. So that the ratio between the mean velocity in that vertical and the velocity at the 4-10ths depth point would be more accurately determined, assuming that it was measured

at the 1-20th rather than at the 1-10th depth, wouldn't it?

A. Your two determinations might agree absolutely.

Q. But assume you did not have any other?

A. Generally speaking, that would be the case.

Q. You would think the 1-20th would be perhaps more accurate than the 1-10th?

A. Yes.

Q. Did you ever make any current meter measurements on the St. Clair, Detroit, Niagara or St. Lawrence Rivers, to investigate the question as to whether or not the rate of travel of the crest of a rise of lake coincided with the rate of travel of the increased discharge corresponding to that stage of lake?

Mr. Hopkins: Objected to as not proper cross-examination.

A. No.

Mr. Adcock: Q. Do you know whether it does or not?

A. No, I do not, definitely.

Q. Suppose that the velocity had been observed at ten points in each vertical of a gaging section, and that this had been repeated ten times at the same stage, within what degree of precision would you say the discharge was known at that stage?

A. Within ½ of 1 per cent.

Q. Well how much less than ½ of 1 per cent, materially less?

A. No, I should think that that covered the range. When we get as close as that, we think we are getting things pretty accurate.

Q. In your direct examination, you stated that the most accurate method of rating a meter was by drawing it through still water. In what other ways have you rated meters?

A. By rating them in running water.

Q. How?

A. Both by running them against and with the current, combining them in pairs, and by comparing the meter to be rated with another one, the rating of one of which is known, in close proximity to each other in the same current.

Q. When the meter is passing through still water, is it operating under conditions the same as the conditions which exist when it is used in determining velocity in a river like the Niagara or St. Lawrence or St. Clair Rivers?

A. We assume that it is.

Q. That is it is running along at an even velocity in the still water?

A. Yes.

Q. And the Niagara River, the threads of the current of the Niagara River are even, a uniform velocity at all times?

A. No, there is a slight variation in the velocity.

Q. So you would consider that the Niagara River, the conditions there were similar to the conditions that exist when rating the meter in still water?

A. We assume that that is the case.

Q. Do the hydraulic engineers of the country agree with you on that proposition?

A. There are lots of them who do not.

Q. Then there is a difference of opinion?

A. Difference of opinion.

Q. In other words, some think that the Niagara River is not a very slow or smooth moving river?

A. Of course it depends upon what part of the Niagara you take.

Q. Take a place like the Bridge Section, with the piers and so forth in there, they disturbed the current to some extent?

A. That reach of the river is a fairly regular one.

Q. Right around the pier?

A. No, there is eddying caused by the pier.

Q. Do all hydraulic engineers agree that you should pick out a section at a bridge where there are bridge piers in the stream as a gaging section?

A. If the conditions are good for measuring the discharge at a Bridge Section, we take that for the reason that observations can be made there more cheaply than where we have to fit up with a boat.

Q. Are you familiar with the statement made on page 5332 of Appendix III, of the report of the Chief of Engineers for 1900 as follows:

"The wetted perimeter of the Bridge Section as developed by the soundings is so broken and irregular, and the water so perturbed and deflected by the bridge piers, and by a caisson that escaped during construction and lies across a portion of span 6, that the validity of results derived from such a section may be questioned," and do you know by whom that statement was made?

A. Yes, that statement was made by Mr. Shenehon in his report upon Niagara observations.

Q. That was the section selected by you and Mr. Shenehon for the 1898, 1899 and 1900 measurements?

A. We began the work of measuring the discharge in 1897, under the Board of Engineers on deep waterways, and having

done considerable work on that section, the Lake Survey continued it.

Q. That was the gaging section selected at that time, was it?

A. At that time.

Q. And that has been used ever since by the Lake Survey?

A. No, since they have measured the discharge at the Open Section below, and recently at a Split Section further down.

Q. At the Split Section they made ten complete discharge measurements, didn't they, in the year 1913?

A. I have forgotten the exact number.

Q. Well, do you consider the statement made by Mr. Shenehon in the report mentioned as a correct statement of the conditions of the Bridge Section?

A. That last statement?

Q. Do you consider the statement made by Mr. Shenehon as a correct statement of the conditions that exist at the Bridge Section on the Niagara River?

A. It is an exaggeration of the conditions.

Q. Did he want to show the difficulties under which he measured within ½ of 1 per cent the exact discharge of the Niagara River, when he made that statement?

A. Why it is natural for the Chief in making a report to describe the conditions as he saw them.

Q. But not to exaggerate them, would he?

A. No, he should not exaggerate them.

Q. Unless it were to show how accurately he could work under very difficult conditions?

A. Why he was attempting to describe conditions as he saw them.

Q. But you say you thought he had exaggerated the conditions?

A. Yes.

Mr. Hopkins: I object to the question as to what the man wanted or thought when he wrote it. Mr. Haskell cannot know what the writer thought. I object to it on that ground, as asking what another man meant or wanted.

Mr. Adcock: Q. You said you thought he had exaggerated the conditions?

A. The conditions, yes.

Q. I am asking you why you think he would exaggerate them. He was under your direction, working under your direction?

A. That was Mr. Shenehon's first experience in discharge

work, and some of those things appeared to him of greater magnitude than they would today.

Q. Mr. Moore made some measurements in 1907 and 1908, did he not, Mr. Sherman Moore, which agreed also with that high degree of accuracy of the true discharge?

A. I believe so.

Q. He had never made any measurements before, had he?

A. I don't know whether he had made any discharge measurements previous to that time or not.

Q. If he stated that he had not made any measurements before that, you would consider his statement true, wouldn't you?

A. What is that question?

Q. I say if he had stated on examination in this record that he never had made any measurements before that you would consider that statement true?

Mr. Hopkins: Objected to as not competent, not properly stating the evidence.

A. That is the natural supposition.

Mr. Adcock: Q. What do you understand by the "Diurnal fluctuation" of a B meter?

A. Diurnal fluctuation of a B meter?

Q. That is the B Haskell meter? I am not referring now to the A meter. That may not have such a fluctuation.

A. I do not know what that can be.

Q. Well, would it be your opinion that there would not be any diurnal fluctuation?

A. It would.

Q. I find on page 5334, Appendix III of the report of the Chief of Engineers for 1900, this statement: "The B meter is credited with a somewhat greater range in its diurnal fluctuations, but it has a remarkable record for the pertinacity with which it clings to a mean rating." What do you understand from that statement?

A. You are calling to mind now by referring to that matter that I did not catch in the previous quesion. That is a daily change in the rating?

Q. Yes.

A. That daily change is so small, and there are only times when it occurs, so that it is negligible so far as any practical results are concerned.

Q. How small is that, Mr. Haskell?

A. I should say in figures it did not amount to more than 2-10ths of 1 per cent.

Q. Is it always within that degree of accuracy?

A. Yes, I should think so.

Q. That is you mean one day the fluctuations will be different from another day, is that correct?

A. It is largely a matter of care of the meter, as to how well it is cared for and how clean it is kept. You see if the meter is kept perfectly clean every day as it should be, and run under absolutely the same conditions, why that diurnal change is very small.

Q. When you say absolutely clean, what care do you refer to? Do you mean it should be kept in a glass case?

A. Oh, no; for instance in certain streams, it may be necessary to clean the meter two or three times in the course of a day.

Q. If you stop work say at night and start in the next morning, will there be a change in the rating between the night before and the next day, when you start in work?

A. It is customary in good work to clean the meter thoroughly as soon as the day's work is done and to oil it, and then it is ready for service the next morning.

Q. Then I take it that it would under register if it got dirty, wouldn't it, on account of friction and so forth?

A. It might, yes. That would be the tendency.

Q. That would be the natural tendency?

A. It would be the tendency.

Q. What is the range? Is that from the mean fluctuations, diurnal fluctuations, is that .2 of variation, or is it between the high and low?

A. Between the high and low.

Q. Then what would you say the variation from the mean might be?

A. One-half of that.

Q. .1 of 1 per cent. Might be less than that?

A. Might be less than that.

Q. Or it might be more?

A. Yes, it might.

Q. But not probable?

A. Not probable.

Q. What reason do you give for saying that it is not probable that it would be more?

A. That depends entirely on the care. We do not consider the meter fit to use unless it is properly cared for day by day and hour by hour, so to speak.

Q. So that a great deal depends upon how often it is cleaned, doesn't it?

A. Principally, yes.

Q. If it was run along for several days without being cleaned, it might under register very materially, might it not?

A. It would depend on how dirty it got.

Q. Upon what did you base the statement in your direct testimony that "There is practically little or no ice effect on Lake Erie; that is so far as the Niagara River is concerned."

A. Why the ice seldom ever blocks the Niagara appreciably. There have been instances when it has been known that it has interferred with the flow for short periods of time.

Q. Did the Lake Survey ever have anyone whose duty it was to make investigations and report as to the conditions of ice in the Niagara River?

A. That was the duty of the party stationed at Buffalo.

Q. What report did he ever make?

A. All that is said in regard to that matter is given by Mr. Shenehon in the 1900 report. I do not recall.

Q. He made those observations with reference to ice, at the time he was working on the Niagara River making the discharge measurements on the preservation at Niagara Falls?

A. No, that was previous to that.

Q. Prior to that?

A. That was prior to that.

Q. Mr. Shenehon was not stationed all the time at Buffalo, was he?

A. That was his headquarters during the investigation.

Q. During the measurements?

A. During the measurements.

Q. How many measurements did he make during the winter there at the Niagara River?

A. I do not recall.

Q. He did not measure there more than during one winter, did he?

A. The records will show that. I think there were parts of two winters that that party worked.

Q. Then it is your belief that no ice gorges occur in the Niagara River?

A. No. Ice gorges do occur in the Niagara River.

Q. That retards the flow, doesn't it?

A. It depends upon where the gorge occurs.

Q. Well, if the gorge occurred in a part of the channel so as to decrease the cross section, it would decrease the discharge, wouldn't it?

A. Certainly. An ice gorge occurred in the Niagara River below the Falls here just a year or two ago. That certainly would not have any effect on the flow from Lake Erie.

Q. Not unless it filled up to the height of the Falls?
A. To the height of the Falls?
Q. You never heard of it doing that?
A. No.
Q. But you have heard of ice gorges, haven't you, above the Falls, which would decrease the cross section of the river?
A. Only on that reach of the river which we consider as the Rapids, which approach the Falls on the American side.
Q. How about ice cover at the Niagara River retarding the flow?
A. It would have a tendency to retard the flow by the friction on the under side of the ice while the stream was frozen over.
Q. Who prepared the portion of the report of International Waterways Commission on the regulation of Lake Erie, 1910, embraced in pages 7 to 22, inclusive, being signed by you, I believe, Mr. Haskell?
A. You referred to this part of the report (indicating)?
Q. Yes.
A. That was written by General Ernst.
Q. That report was signed by you, wasn't it, Mr. Haskell?
A. It was.
Q. You subscribe to everything stated in that report?
A. I do.
Q. Referring to page 19 of this report and paragraph 33, as follows:

"Title: Ice Jams. During every winter ice jams form on Horseshoe Reef at the head of Niagara River. The ice in the lake is blown toward the outlet by a southwest wind and is piled upon the shallow reef where it forms an ice jam extending from near the bottom to several feet above the surface of the water.

In some instances the bergs have been 20 to 30 feet high. The proposed regulating works being placed about a mile below Horseshoe Reef would aggravate the difficulty. The neck of the outlet might become so effectively blocked with ice that the flow of the river would be materially decreased as was the flow of the St. Clair River in the winters of 1901 and '02. If those conditions should exist, a severe southwesterly storm, such as has occurred on numerous occasions, would inundate the lower part of Buffalo. These ice jams seriously interfere with navigation. The average date of opening navigation in the spring at Buffalo is April 9, while at Cleveland the average date is March 23. The difference of 17 days in the dates of opening of the two Lake Erie ports

is due to ice jams. It is probable that it would be materially increased by the construction of the regulating works. It is to be observed that the ice jams would make it difficult to maintain the works." Was the statement made there true with reference to ice jams in the Niagara River?

A. Yes.

Q. You consider, do you, that they would retard and decrease the flow from Lake Erie through the Niagara River?

A. The effect of those jams upon Horseshoe Reef is very small on the flow of the river.

Q. How do you know?

A. Because they are outside of the main entrance to the river.

Q. Don't they decrease the cross section at that point?

A. The cross section at that point is so large that a good portion of it could be cut off and the river still have nearly its full capacity.

Q. How would Buffalo become inundated, as stated in this report, if the flow of the Niagara River were not decreased?

A. That is the case when the dam is in there. That depends upon the dam being placed in that location, and causing an ice jam against the dam.

Q. Have you ever observed the condition of frazil or anchor ice in the Niagara River?

A. No, I have not.

Q. Isn't it a fact that there is considerable of that character of ice, which retards the flow?

A. Not above the Falls.

Q. Frazil or anchor ice in a river will retard the flow, will it not?

A. Certainly it can become of such quantity.

Q. You don't know whether there is any there or not, do you?

A. I never have seen any above the Falls.

Q. Did you ever look for any?

A. Yes.

Q. When and to what extent?

A. During the time in which those observations were going on.

Q. It was only during that time?

A. That is all, during the years with which I was connected with the work.

Q. I call your attention to page 24 of Mr. Shenehon's work entitled "Preservation of Niagara Falls, Senate Document Number 105, 62nd Congress, First Session as follows:"

"From January to May, ice conditions serve to impede the outflow so that the volume is sometimes 10 per cent less than the summer discharge for the same lake level, and in the mid-summer, the growth of aquatic plants in the river bed diminishes the clear channelway and increases the resistance above that of the smooth bottom. For the same level, the river passes approximately 1 per cent more water in May than in September."

Having in mind this statement which I have just read, what would you say with reference to whether there is practically little or no ice effect on Lake Erie, that is so far as the Niagara River is concerned.

A. It is all of short duration.

Q. That is from January to May?

A. Yes.

Q. Of each year?

A. You can't say it occurs each year.

Q. You don't know whether it occurs each year at that point?

A. I know there are some years in which it does not occur.

Q. The same as there are some years in which it does not occur on the St. Clair River?

A. Exactly.

Q. Suppose that on any of the rivers connecting the Great Lakes there has been made with the supposed care of the Lake Survey 147 measurements of discharge covering a range of lake stage of 0.76 feet, with what degree of accuracy would you say the discharge of the river in question was known corresponding to the mean of the elevations at which the discharges were observed; and I assume that this is with the Haskell meter?

A. I should say we knew the discharge within 1 per cent.

Q. No closer than that, Mr. Haskell?

A. That is close enough for all practical purposes.

Q. I understood you to say that if you only had ten, you would get within ½ of 1 per cent. That was in the Split Section of the Niagara River?

A. I will make that ½ of 1 per cent.

Q. Within ½ of 1 per cent?

A. Yes, within ½ of 1 per cent.

Q. You don't know whether it would be materially less than that or not?

A. No.

Q. Suppose that on any of the rivers connecting the Great Lakes there had been made with the usual care of the

Lake Survey 126 measurements of discharge covering a range of lake stage of 1.42 feet, with what degree of accuracy would you say the discharge of the river in question was known corresponding to the mean of the elevations at which the discharges were observed?

A. Within the same percentage, ½ of 1 per cent.

Q. And you would give the same answer, assuming that on those rivers there had been 57 observations made covering a range of lake stage of 0.76 feet, wouldn't you?

A. Yes.

Q. Suppose that on the same river we had 150 similar observations to those referred to in the preceding questions, covering a range of lake stage of 0.98 feet, not included in the preceding group, how accurately would you say the discharge was known corresponding to the mean of the elevations at which the discharges were observed?

A. Within the same percentage.

Q. And your answer would be the same, assuming in the same river there were 102 observations, covering a range of 2.50 feet?

A. 2.50 feet. At the center of gravity? I should say it was within ½ of 1 per cent.

Q. You would give the same answer, assuming that there were 36 observations, covering a range of lake stage of 1.67 feet?

A. 36, that is reducing the number quite a little. I should not expect quite as high an accuracy.

Q. Well then you would say it would be about ½ of 1 per cent?

A. About ½ of 1 per cent.

Q. Suppose that you knew the discharge of a certain river at a certain elevation within ½ of 1 per cent, and suppose that you also knew the discharge at another elevation of the same river within ½ of 1 per cent, and assume that the discharges were 203,382 cubic feet per second and 187,082 second feet, within what percentage of accuracy would you know the difference between them?

A. It ought to be by the same accuracy.

Q. Is it not the difference between the discharge?

A. Between the two?

Q. Yes.

A. Well, it would be one-half of that.

Q. Do you want the question read again?

A. Yes.

Q. (Question read.) That is between the discharges of the two elevations?

A. Substantially within ¼ of 1 per cent.

Q. Suppose under the same conditions the discharges at one elevation was 220,820 cubic feet per second, at another elevation it was 191,846 cubic feet per second, within what per cent of accuracy would you know the difference between them?

A. I think I misunderstood the question.

Mr. Hopkins: Difference between what, discharges?

Mr. Adcock: Yes.

(Question read.)

A. Within 1 per cent, if I have got that question right.

Mr. Hopkins: Do you wish to correct your other answer?

Mr. Adcock: Q. Why do you say within 1 per cent?

A. The error between the two might be on opposite sides.

Q. But by the theory of probabilities which you refer to here, it might be one side or the other in one case and one side or the other in the other case, and one might offset the other?

A. It might.

Q. So there would not be any difference?

A. There might not be any difference.

Q. You might know it within 100 per cent of correct?

A. You might know it exactly; the error might be 1 per cent.

Mr. Hopkins: That was the second question you were answering. I understand you did not understand the first question also?

A. Yes.

Mr. Adcock: You want to answer 1 per cent to the other?

A. Yes.

Q. What would you say the probable per cent of accuracy would be? You say it might be as great as 1 per cent, the difference?

A. The probable percentage?

Q. Yes.

A. About 1-10th of 1 per cent.

Q. Now suppose that you knew the discharge of a certain river at a certain elevation within ½ of 1 per cent, and suppose that you also knew the discharge at another elevation of the same river within ½ of 1 per cent, and assume the discharges were 249,046 cubic feet per second, and 216,600 cubic feet per second, within what per cent of accuracy would you know the difference between them?

Mr. Adcock: If Mr. Haskell thinks he does not understand the question, I would like to have him state what his under-

standing of the question is in his own words. There has been some suggestion made that he does not understand the question. I presume that is from the answer that has been given. When I say "question" I mean the three questions that have been propounded with reference to substantially the same situation, but using different discharges for different elevations.

A. I should make substantially the same answer to this as I did to the previous question, as I understand it.

Q. That is that the possible inaccuracy would be 1 per cent?

A. 1 per cent.

Q. And a probable inaccuracy would be 1-10th of 1 per cent?

A. Approximately that.

Q. If the difference in elevation between the first two discharges considered was 0.57 feet, assuming the conditions of the preceding questions and the answers thereto, within what degree of accuracy would you know the change of discharge for a change of elevation of 1 foot?

A. With the same precision.

Q. If the difference in elevation between the second two discharges was 1.31 feet, assuming the same conditions presented in the previous questions and your answers thereto, within what degree of accuracy would you know the change of discharge for a change of elevation of 1 foot?

A. Within the same precision.

Q. If the difference in elevation between the last two discharges considered was 1.11 feet, assuming the conditions mentioned in that question and your answer thereto, within what degree of accuracy would you know the change of discharge for a change of elevation of 1 foot?

A. Within the same precision as I see it. Maybe I did not understand the question.

Q. That is there might be an error of 1 per cent and a probable error of 1-10th of 1 per cent?

A. Yes.

Q. What is the meaning of the term increment as used in this case?

A. The meaning of the term increment?

Q. Yes.

A. That is it is the increase in discharge per unit—

Q. You know we have not had a real good definition of increment by complainant's witnesses so far. I would like to have you give a comprehensive definition, so that the Court will understand it.

Mr. Hopkins: I object to the statement of counsel. It does not involve the facts. I move it be stricken out.

The Witness: I have answered that question once, Mr. Adcock.

Q. Have you?

A. Yes.

Mr. Adcock: It is not a comprehensive, specific statement.

Mr. Hopkins: Do you want him in giving the definition of increment to repeat what he said before, or do you know that already? Or do you want him to add to it anything to make it more comprehensive?

Mr. Adcock: Just assume that I do not understand what increment is.

Mr. Hopkins: You are entitled to ask the question over again.

Mr. Adcock: I am perfectly willing to ask it over again, if it has already been asked before, which I do not admit.

The Witness: Shall I go ahead?

Mr. Adcock: Yes.

A. By the increment of discharge in current meter work, we mean the increase in volume of discharge per unit of rise of the lake or the river at the particular point. We usually speak of that as the increase per foot, and divide it up into the tenth of a foot if a person is more concerned with the smaller unit, speaking of it as the tenth; or sometimes it is in inches, in which case it would be the increment per foot divided by 12.

Q. You say in current meter work?

A. In discharge work and in current meter work.

Q. It does not mean anything different in work of other kind?

A. Oh, no, it is a term that has grown out of discharge measurements of rivers, open channels.

Q. You may have an increment of population per year in a city?

A. Yes.

Q. The same thing?

A. Same thing.

Q. What I want to understand is, you said current meter work; it has not any different meaning in current meter work than in any other kind of discharge work?

A. Oh, no, it is the increment.

Adjourned to Thursday, February 26, 1914, 10:00 a. m.

Thursday, February 26, 1914, 10:00 a. m.

EUGENE E. HASKELL resumed the stand and testified further as follows:

Mr. Hopkins: I understand that Mr. Haskell wants to make some corrections in regard to his answers to the questions yesterday in reference to the error in those differences of discharges, referred to in the last questions when we adjourned yesterday afternoon. Do you want to make some corrections, Mr. Haskell?

The Witness: Yes.

Mr. Adcock: Q. This is after further consideration of the questions?

A. After further consideration of the questions.

Mr. Hopkins: Let the Commissioner read them to you if you want.

Mr. Adcock: Do you want them read to you, or do you have in mind the corrections that you wish to make in your answers to the questions?

A. I think I have in mind the point that I want to bring out and that is in regard to the error in the increment. That might be anywhere from ½ of 1 per cent to 10 per cent, that is approximately.

Q. You mean the difference between the discharges?

A. The error in that difference.

Q. The error in that difference?

A. Yes.

Q. That would be within the points which you mentioned?

A. Yes.

Q. And it might be as low as 1-10th of 1 per cent, which you mentioned?

A. No, ½ of 1 per cent.

Q. ½ of 1 per cent?

A. ½ of 1 per cent.

Then I want to make a correction in regard to the statement which I made when you read to me that passage from Mr. Shenehon's report on the Niagara River. I stated that that was his first piece of discharge work. I was in error about that, because Mr. Shenehon did assist in the observations which were made at Sault Ste. Marie the winter of 1895-'96; and also assisted in the computations which were made at that time. I had forgotten those.

Q. What did Mr. Shenehon do at that time?

A. He assisted in making the observations. There were three of us concerned directly with the making of observations, and he made observations a part of the time; Mr. Sabin a part of the time and myself a part of the time on the Spry Dock Section.

Q. What was his position?

A. Mr. Shenehon's?

Q. Yes.

A. Mr. Shenehon was assistant engineer in the U. S. Engineer Office at that time.

Q. What were his duties in connection with the making of discharge measurements on the St. Marys River, that you mentioned?

A. The work that winter was the question of preliminary work, or starting really in the investigation of lake levels, and there were several of us concerned in it, and were on duty from time to time in connection with the work in the river.

Q. That is when you say interested in it, you mean interested in making those particular measurements, or connected with making those measurements?

A. He assisted in making those measurements.

Q. What particular thing did he do in connection with making the measurements? Did he read the meter at the soundings?

A. He made the observations, that is the observations for velocity.

Q. He didn't have anything to do with the soundings?

A. Not that I recall.

Q. Or were any soundings made?

A. Yes, the soundings were made by what was known as the river party of the Engineer Office. It was a party that was fitted up purposely for the making of soundings.

Q. The current was slow there, was it?

A. Yes.

Q. Was this party that did the sounding connected with the Lake Survey?

A. No, they were connected with the river work or improvement work.

Q. That was the Engineer Office?

A. That was the Engineer Office.

Q. At the Soo?

A. At the Soo.

Q. Would the Lake Survey take the records of soundings

made by another engineer office of the United States Government?

A. Yes, where they were made as carefully as those were.

Mr. Hopkins: Did you want to make any further correction in regard to the range, in connection with that percentage coming from two discharge observations?

A. Really I think I have taken care of that in this matter. I think it answers that question.

Mr. Adcock: Q. These were not necessarily two single discharge observations that the questions embraced, were they?

A. No, I think not.

Q. They were the mean?

A. Yes.

Q. Of a number of observations?

A. Yes.

Q. Is it your proposition that the difference between the discharge at a certain mean of a group of observations at certain elevations and the discharge corresponding to the mean of another group of observations would be from ½ of 1 per cent to 10 per cent in error?

A. It might.

Q. Why do you limit it to ½ of 1 per cent, might it not be absolutely accurate?

A. Yes, it might be absolutely accurate. We simply state that as a lower limit, indicating good work, indicating precision.

Q. In your previous answers to questions as to the percentage of accuracy of the measurements with reference to flow, when you stated it was within ½ of 1 per cent of accuracy, you meant, did you not, that it was between zero and ½ of 1 per cent?

A. Yes.

Q. So now, on the same reasoning, and with reference to your answer as to the percentage of accuracy in the determination of the difference between the discharges of two elevations mentioned, you mean between zero and ten per cent?

A. Yes, that is the range might be so small as to—

Q. When water flows around a curve in a river, does the current follow the axis of the channel, or does the water tend to impinge on the concave bank?

A. It tends to impinge on the bank.

Q. That is pile up on that side?

A. Pile up on that side.

Q. Then would the current be oblique to a section normal to the axis of the channel?

A. Partially so.

Q. What is the result of the water piling up along the concave bank?

A. A tendency to increase the head at that point.

Q. What is the effect as to creating a reverse cross current in the bottom of the stream?

A. It would have the tendency to deflect the current from that bank and to send it toward the center of the channel.

Q. Or the convex bank?

A. Yes.

Q. Then the direction of the current at the top and bottom of the stream would make different angles with the axis of the stream, would it not?

A. The section might be such that it would.

Q. Wouldn't it be so on any curve in a river?

A. As to magnitude of that effect, it would depend upon the velocity. That is if the current were feeble that action would not amount to much of anything. If it were strong, it would amount to considerably more.

Q. If it were necessary to correct for that condition at the top, for the current at the top of the water, wouldn't it be necessary to make similar correction for the current at the bottom?

Mr. Hopkins: I make an objection to all this line of questioning, as not proper cross-examination.

Mr. Adcock: Not for the purpose of arguing the proposition, but merely so it may appear in the record, I will call your attention to the fact that the witness in direct examination testified with reference to the effect of an oblique current at certain hydraulic sections or gaging sections. I do not know whether counsel wishes to protest further or not.

The Witness: Shall I answer the question?

Mr. Hopkins: Yes.

A. It might be necessary to make the correction; that is the angle might be so great as to make it necessary to make the correction to the bottom velocities as well as to the surface.

Mr. Adcock: Q. At a point near mid depth, would or would not the two motions blend to produce a flow nearly axial?

Mr. Hopkins: I insist that the question be explained.

A. It would approximate to normal to the cross section. That would be the tendency.

Q. That is there would not be as great an obliquity at mid depth as at top or bottom?

A. That probably would be the case.

Q. Was there any obliquity of current on the split sections on the Niagara River?

A. Not to any appreciable extent.

Q. Was that your understanding when you testified on direct examination as to the accuracy of those measurements?

A. It was.

Q. If it should appear that the obliquity was determined by floats approximately 14 feet long and the depth of the river was something over 30 feet, and a correction was made for such obliquity, then the correction probably would be too great, would it not?

Mr. Hopkins: You mean at that place?

Mr. Adcock: At the Split Section.

A. I see no reason why it should be too great.

Q. Then how do you reconcile that conclusion with the former answers to the previous questions, with reference to the effect of an oblique current?

A. I do not see that it needs to be reconciled.

Q. Well, will you explain why you think it is unnecessary to reconcile it?

A. In this case of using the float, you get the direction of the current with respect to the plans of the cross section, and you make a correction for that.

Q. But you only get the obliquity at the top?

A. At the top.

Q. How about the obliquity at the bottom, that you mentioned a little while ago, in a reverse direction?

A. The correction might be the same or it might not. It would depend entirely upon the cross section.

Q. How about the portion of the stream where the current would be axial or normal to the cross section?

A. Normal to the cross section? That would not require any correction.

Q. And if you corrected that, you would reduce the discharge in that section, wouldn't you?

A. Yes.

Q. Then you did not remember, did not have this source of error in mind, when you testified as to the percentage of accuracy of these ten discharge measurements at the Split Section on the Niagara River?

A. Yes, I did have that in mind.

Q. But did you know that there was a correction made for the obliquity of the current?

A. On that section?

Q. On that section at that time?

A. I don't recall.

Q. Then it must follow that you did not take it into consideration at that time?

A. I took into consideration—or took for granted that that work was done with the same precision with which all of the Lake Survey work had been previously done.

Q. Which you consider to have a very high character?

A. I do.

Q. And the methods used and laid out for that work are precise?

A. We try to make them as precise as possible, to get at the truth as nearly as it was attainable.

Q. Was there ever any correction for obliquity of current at any other gaging sections upon any of these rivers?

A. Yes, correction was applied to the observations made from the International Bridge at Sault Ste. Marie. I do not recall whether it was applied at any other section or not.

Q. Did Mr. Shenehon correct for the obliquity of the currents created by the eddies around the International Bridge piers, at the International Bridge Section of the Niagara River?

A. It has been so long since I have seen those computations that I could not recall.

Q. If he did not, should he have done so?

A. He should have done so if they were of a magnitude to be of importance.

Q. That would depend upon his personal opinion at the time that he made the measurements, wouldn't it?

A. And the observations which he made.

Q. And his conclusions drawn from the observations as he made them?

A. Yes.

Q. Do you believe the equations of discharge shown on pages 3546 and 3547 of the report of the Chief of Engineers for 1912, to be applicable to the conditions existing between 1860 and 1890? That refers to all the rivers in controversy.

Mr. Hopkins: Objected to as not proper cross-examination. He has not testified to the Lake Survey equation. He gave his own.

A. (After referring to equations indicated.) This is the first time I have ever seen these equations.

Q. (Question read.)

Mr. Hopkins: I object to the question again as not cross-examination. It is not a matter that the witness has testified concerning, and there appear to be complications there that I do not think he ought to be called on to answer. He can use his own discretion, as to whether he understands it.

A. I should say that they were applicable so far as the St. Clair and the Niagara Rivers are concerned. I should not care to express an opinion in regard to the St. Marys River and the St. Lawrence River until after I have had time to read the report in full.

Mr. Adcock: Q. If the equation for the St. Lawrence River represents the present conditions and if a proper correction were made for the effect of the Gut Dam, then would you think the equations applicable to the St. Lawrence River for the period mentioned?

Mr. Hopkins: Same objection to that as to the prior question. In other words, does that additional matter in that question change your former answer?

A. No, I should prefer to stick by my former answer. Canadian Channel improvements in the North Channel, have undoubtedly had some effect upon the discharge of the St. Lawrence River, and those were made after 1890, if I remember correctly.

Mr. Adcock: Q. What were they, Mr. Haskell, that would affect the discharge of the St. Lawrence River?

A. You see the Canadian Government cut what is known as the North Channel, which would have a tendency to increase the discharge at that particular point.

Q. Do you remember just when that was done?

A. I do not. It was some time as I recall it in the latter part of the nineties and the first part of 1900-'01, it was a contract continuing over several years.

Q. Was that before or after the construction of the Gut Dam?

A. That was before.

Q. Is that the channel above the Galope Rapids?

A. Yes.

Q. Was it constructed at the time of the original discharge measurements on the St. Lawrence River?

A. I imagine it had been completed.

Q. That is it was not opened at that time?

A. That is my recollection of it.

Q. So that at the time those discharge measurements were made, there was no effect from this channel, the North Chan-

nel that you speak of; no effect apparent upon the discharge of the St. Lawrence River?

A. If the work had been completed, of course the discharge formula which is given would represent the conditions after the completion of the work, and as to just when that work was finished, I could not say. I remember it being in progress.

Q. If it were opened afterwards, then there would be no effect of it upon the earlier discharge measurements, of course?

A. No.

Q. Then if you corrected this equation to correspond with the conditions of the river during the earlier measurements, you would provide for the effect of this channel and the Gut Dam also, would you not?

A. Yes.

Q. Assuming the corrections to be made, then would the equation for the St. Lawrence River shown in the report mentioned, pages 3546-7, be applicable to the conditions existing between 1860 and 1890?

Mr. Hopkins: I again object to that line of questioning. It is eminently unfair. The witness has stated that he has not read the report; and without reading the report, he cannot know the conditions taken into consideration in forming that equation, wherein it is stated that there is probably an uncertainty and inaccuracy in the measurements of the St. Lawrence; also that the range of stage of the observations is much less than the actual range of stage, and many other conditions in the report itself to affect that equation. And I do not think the witness ought to be called upon to answer.

Mr. Adcock: I wish to protest against the form of objection made, as it is evidently made for the purpose of instructing the witness as to what counsel thinks his answer to the question should be.

Mr. Hopkins: I simply object to making a witness answer, who seems to be willing to answer on a report that he said he does not know anything about.

Mr. Adcock: Q. Then if you will examine the report, take all the time you want to examine the report and answer the question.

Mr. Hopkins: It is not proper cross-examination. I instruct him not to take the time to do it unless counsel wants to wait for him to do it; and move to strike out the whole deposition.

Mr. Adcock: The witness testified in direct examination

that he had examined and was familiar with the later discharge measurements made, and he gave an opinion as to the accuracy of those measurements.

Mr. Hopkins: He did not testify to that equation in that report.

Mr. Adcock: The equation is the reduction of the observations.

Mr. Hopkins: I suggest, Mr. Commissioner, that we adjourn to give the witness time to read the report.

(Question read.) "Assuming the corrections to be made, then would the equation for the St. Lawrence River, shown in the report mentioned, pages 3546-7, be applicable to the conditions existing between 1860 and 1890?"

A. They would be within the range of the observations used in the discharge work.

Q. What do you mean by within the range of the observations used in the discharge measurements?

A. That is the conditions previous to 1890, where the stage of Lake Ontario was above that at which discharge measurements were made, it might not be applicable.

Q. How great an error would result therefrom, assuming that condition?

A. It is hard to say.

Q. Would it be 50 per cent?

A. Not at all likely.

Q. Ten per cent?

A. It might be as great as 10 per cent.

Q. Do you think it would be as great as 10 per cent?

A. I should not care to express an opinion.

Q. Is that based on the proposition that the increment of the St. Lawrence River is best expressed by a curve rather than a straight line?

A. Yes.

Q. I refer you to table XXIII, appearing upon page 53 of the Report of the International Waterways Commission entitled: "Regulation of Lake Erie," wherein the increment of the St. Lawrence River is shown for various stages; and I will ask you, after examining that table, to state whether you consider the statements made there accurate?

A. (After examining table referred to.) They are substantially so, and are based upon the data that we had up to the time of making this study.

Q. They are based upon the Lake Survey measurements, aren't they?

A. They are.

Q. Didn't you say in your direct examination that you thought the increment was expressed about as well by a straight line as a curve?

A. I don't recall having made that statement, but within certain limits it is practically true.

Q. Well, what are the limits?

A. For small changes of stage, say of a foot.

Q. In other words, would you change the increment every foot?

A. Yes, I think that is substantially the form upon which these equations were derived.

Q. You have made a very careful study of the discharge measurements made by the Lake Survey upon these different rivers, and you have taken occasion in the testimony to express an opinion as to the accuracy of the discharge increments, as to the accuracy in the increments which have been derived from those discharge measurements, within very close limits. I wondered if you could not give us a closer estimation of the applicability of the equation for the St. Lawrence River mentioned to different elevations, elevations beyond the range of the measurements, closer than the 10 per cent which you have mentioned. For instance, you have stated that the discharge measurements of the Niagara River were within less than ½ of 1 per cent of true, the discharge. That is a very small percentage, isn't it?

A. It is.

Mr. Hopkins: Just a moment. Have you stated that correctly, Mr. Adcock, as to his testimony?

Mr. Adcock: Can you answer that? Can you give us a closer estimation than the 10 per cent which you mentioned in accuracy at other elevations?

A. I should be willing to stand by the results as given in here (indicating report referred to) for the probability of that increment beyond the stages of the observations.

Q. Within what per cent?

A. Oh, within 10 per cent.

Q. You cannot give it to us any closer than that?

A. No, I should not care to express an opinion any closer than that.

Q. Is this because of the difficulties of measurement on the St. Lawrence River?

A. No, it is because we have no observations beyond that point, and we are simply predicting as to what we think is the case beyond those limits.

Q. Then it is your opinion that the law of a curve as estab-

lished by the discharge measurements is not correct beyond the range of those discharge measurements, or the limits?

A. It may be an error beyond those limits by as much as 10 per cent.

Q. You think it is?

Mr. Hopkins: This is referring to the St. Clair and Niagara Rivers, I understand?

The Witness: The St. Lawrence River.

Mr. Adcock: Q. I assume in that connection that you are basing your answer upon the records of discharge measurements and gage readings, and so forth, in the Lake Survey?

A. From the Lake Survey data.

Q. (Question read.)

A. Yes.

Q. Assuming the mean open season elevation of Lake Huron, from 1860 to 1883, inclusive, to be as shown in Williams' Exhibit 34, Table XVIII, 581.99, and the mean of Lake St. Clair similarly, 576.39, what was the average discharge for this period?

A. 222,400.

Q. Assuming the mean open season elevation of Lake Huron from 1890 to 1901, inclusive, to be similarly 580.565, and that of St. Clair 575.155, what was the average discharge for that period?

A. 193,000.

Q. Assuming the average open season elevation of Lake Erie for the former period to have been as similarly indicated, 573.14, what was the mean discharge of the Niagara River for the period, by the equation on page 3547?

A. 221,591.

Q. Assuming the average open season elevation of Erie from 1890 to 1901, inclusive, to be, similarly, 572.175, what was the mean discharge of the Niagara River for this period?

A. 200,800.

Q. Assuming the average open season elevation of Lake Ontario for the early period, similarly, was 246.72, and referring to the increments used in Table XXIII of the report of the International Waterways Commission on the regulation of Lake Erie, 1910, and making such corrections as may be necessary, if any for the Gut Dam and the North Channel referred to, what was the mean discharge of the St. Lawrence River from 1860 to 1883, inclusive, by the International Waterways Report?

Mr. Hopkins: I object to all this line of questions as not

proper cross examination, and also on the ground that he has not named any correction to be made for the Gut Dam and the North Channel referred to. It does not appear in evidence what correction should be made by him.

Mr. Adcock: I will amend that question. Making such correction as you think necessary.

Mr. Hopkins: Same objection.

Mr. Adcock: Q. Do those equations appearing in the International Waterways Commission Report, Table XXIII, refer to the conditions before the Gut Dam?

A. They do.

Q. So there would be no correction for the Gut Dam or North Channel?

A. There would be no correction.

Q. Then with that in mind, will you answer the question which is pending?

A. You want me to compute it?

Q. Yes.

A. Will you put that in terms of the Ogdensberg gage, for which the formula is given here?

Q. Assume in the preceding question that the corresponding Ogdensberg gage is 245.80?

A. It will take two hours to compute this, if not more. The St. Lawrence River in the period from 1860 to 1883, inclusive, would be 280,000 flat.

Q. Assuming the average open season of Ontario, similarly, from 1890 to 1901, to be 245,635, and referring to the International equations, mentioned in the International Waterways Commission Report, what was the mean discharge of the St. Lawrence River for this period?

A. That would be 243,600.

Q. By how much did the flow of the St. Clair exceed that of the Niagara in the earlier period?

A. The St. Clair was 222,400, the Niagara 221,600; 800 cubic feet per second.

Q. By how much was the St. Clair discharge less than that of Niagara in the second period?

A. The difference is 7,800.

Q. How was the excess of water in the former period, coming from the St. Clair River, amounting to 7,800 cubic feet per second, plus 800 cubic feet per second, making a total of 8,600 cubic feet per second, as compared with the later one, disposed of after reaching Lake Erie?

Mr. Hopkins: I object to that. The former comparisons were upon certain assumptions, which had in some of them

degrees of error. Therefore, there is no foundation for that question.

Mr. Adcock: If counsel wishes to prompt the witness as to the answer to a question in the form of an objection, I see no way to stop him except by protesting in the record.

Mr. Hopkins: In answer to that statement I insist upon my objection that the other questions were purely hypothetical, and now he asks a question as to what did become of it in fact. The question is improper and unfair.

Mr. Adcock: I wish to make the same statement as to the last statement of counsel. I think my observations apply to a greater extent to the last statement than to the former statement made by counsel.

Recess to 2:00 p. m.

Thursday, February 26, 1914, 2:00 p. m.

EUGENE E. HASKELL resumed the stand for further cross-examination by Mr. Adcock and testified as follows:

Q. (Question read as follows: "How was the excess of water in the former period coming from the St. Clair River amounting to 7,800 cubic feet per second, plus 800 cubic feet per second, making a total of 8,600 cubic feet per second, as compared with the later one, disposed of after reaching Lake Erie?")

A. In my judgment that water did not reach Lake Erie; there is an error in the increment as applied to the St. Clair River; that that as given in this Lake Survey Report for 1912, is too high.

Q. In other words, Mr. Haskell, your St. Clair increment will not compare favorably with the Niagara increment?

A. State that again?

Q. (Question read.)

Mr. Hopkins: You mean the one of the Lake Survey?

Mr. Adcock: The Lake Survey increment for the St. Clair River will not compare favorably with the Niagara increment?

The Witness: That one, as given there, I should say was too large, as compared with the Niagara River.

Q. How many discharge measurements were considered by the Lake Survey on the St. Clair River, in determining their increment for that river?

A. I have forgotten those.

Q. About 400, wasn't it?

A. I do not think as many as that on the St. Clair River.

Q. Well, approximately that. Was it more or less than 400?

A. I should say it was less.

Q. How much less?

A. I had got it in mind that it was somewhere in the neighborhood of 200. Those are figures that I do not carry around in my head.

Q. I will ask you if, as a matter of fact, there were not 297 separate discharge measurements at the Dry Dock Section?

A. 297.

Q. And about 180 measurements at the Gorge Section?

A. I had forgotten the figures. I would not attempt to give them. They are a matter of record.

Q. And on the Niagara River there were approximately 218 on the Bridge Section, the International Bridge, and about 121 on the Open Section?

A. That would make 339.

Q. As against about 500 in the measurements on the St. Clair River?

A. On the St. Clair River.

Q. And it is because this increment of the St. Clair River will not check with the increment of the Niagara River that you say that it should be lower than the amount stated by the Lake Survey?

A. Lower than the amount stated by the Lake Survey in that report. You see the International Waterways Commission, we made that 18,900.

Q. How did you get that?

A. It is from the reduction made in the office of the Commission from the observations that existed up to the time of the report, our report.

Q. There have been a large number of observations made since then, haven't there?

A. There have.

Q. And I believe you stated that the discharge measurements and the work in connection with making the discharge measurements, gage readings and so forth, and the computations necessary to derive an increment on the St. Clair River, were as accurately done as the same character of work on the Niagara River?

A. I assumed that.

Q. I presume you assumed also that the Niagara River is an easier river to measure than the St. Clair River?

A. No easier to measure. The complications there are less.

Q. On account of passing boats and things like that?

A. No, I didn't have reference to that. I had more particularly reference to the question of back water.

Q. Well, what investigations have you made with reference to the effect of back water upon the derivation of the increment of the St. Clair River?

A. Well, I have made none myself further than watching computations which were made in regard to that work. Mr. Russell produced a report upon it and Mr. Sabin produced a report upon it.

Q. You put considerable weight on Mr. Russell's report, did you, and Mr. Sabin's report?

A. Certain parts of Mr. Russell's report, I think, are excellent.

Q. And certain parts of Mr. Sabin's?

A. Yes. In fact I could accept Mr. Sabin's report more in whole than I could Mr. Russell's.

Q. You approved Mr. Russell's report, didn't you?

A. I did.

Q. What was that report called, do you remember, and when was it published?

A. That was in 1904, Lake Survey Report, I think.

Q. Well, these measurements on the Dry Dock Section and on the Gorge Section checked, did they not?

A. Yes, I think within reasonable limits.

Q. That was one of the tests, or the test, which you used to determine the accuracy of the results obtained?

A. Yes.

Q. In the discharge measurements?

A. Yes.

Q. I refer you to the report of Mr. Thomas Russell, Assistant Engineer, dated Detroit, Michigan, May 18, 1904, which begins at page 4069, Report of the Chief of Engineers for the year 1904, and ask you to point out what portions of that report you agree with and what portions you disagree with (handing witness same)?

A. I agree substantially with the increment, as given here by Mr. Russell in his figures.

Q. What was that?

A. It worked out here substantially 20,700.

Q. How was that worked out?

A. It comes from the figures which he gives here.
Q. What page are you referring to?
A. I was referring then to page 4078.

I should also agree with Mr. Russell in the conclusions which he has reached, which are expressed in his paragraphs 22 and 23, on page 4131.

Q. Relative to what?
A. Relative to the effect on Lake levels.
Q. That is based, I suppose, on the increments that he derived?
A. That he has derived in his reports.
Q. And only on that?
A. Certainly. I have not read all of those through.
Q. You haven't pointed out anything that you disagree with yet, Mr. Haskell?
A. I should hardly agree with Mr. Russell in regard to paragraph number 4, where he refers to the discharge of the St. Clair and Detroit Rivers considered as one in terms of height of Lake Huron and Lake Erie.
Q. Considered as what?
A. That is on page 4129.
Q. You say you hardly agree with him?
A. That is he bases his formula upon the stages in those two lakes, leaving out of the question Lake St. Clair. I should not agree with him on that point.
Q. At all?
A. No, I should say—
Q. He was all wrong on that?
A. No, I would not say he was all wrong, but it would not be my way of attacking the problem, because I think Lake St. Clair cuts something of a figure in that.
Q. Well, does he get substantially the result from that, or how much is he in error?
A. I see that Mr. Russell limits it here himself, in a further sentence which I did not notice before. He said "The formula is only applicable for mean values covering a considerable period, at least one month."
Q. Then you would agree with his statement?
A. Well, I see he qualifies that.
Q. Having in mind this qualification of Mr. Russell's, you agree then with paragraph 4?
A. Yes, so far as any agreement is needed.
Q. Is there anything else you disagree with?
A. I find nothing in a preliminary examination. Possibly

if I were to study it closely in detail I could raise some questions.

Q. That is in some of the details?

A. Some of the details, mainly.

Q. But the general conclusions which he reaches, you agree with, do you?

A. Substantially so.

Q. What is the difference in the discharge of the St. Lawrence River between the two periods mentioned?

A. That was given as 280,000 for the period 1860 to 1883, and is 243,600 for the period 1890 to 1901, giving a difference of 36,400.

Q. A range of what?

A. It is a range of 1.08 feet.

Q. What increment would that show?

A. That would show an increment of 33,700.

Q. Assuming the increment used by Mr. Russell, which you have just stated, what would be the discharges of the St. Clair River, mean discharges for the two periods mentioned?

A. That is you refer to the previous figures which we had on the St. Clair, for the period 1860 to 1883?

Q. 581.99.

A. That was 222,400.

Q. Using Mr. Russell's equation, which you say you agree with, see what you get then?

A. I do not see the point to the question there.

Q. (Question read.) For the difference of discharge of the two periods?

Mr. Hopkins: I object to the form of that question; the part "which you agree with" is a question of record, and the attorney ought not to repeat the record.

A. 28,860 for the 1.43 feet; for the increment per foot there would be 20,100.

Q. What were your discharges?

A. 218,660, and 189,800.

Q. How much did the flow of Niagara exceed the flow of St. Clair during the earlier period, according to more recent computations?

A. The Niagara is 3,000 greater.

Q. What is the situation with reference to the second period?

A. 11,000.

Q. Then how was the excess of water in the former period coming from the St. Clair River amounting to 11,000 cubic

feet per second, minus 3,000 cubic feet per second, making a result of 8,000 cubic feet per second, as compared with the later on disposed of after reaching Lake Erie?

A. I should say that water did not get to Lake Erie.

Q. You think that water did not get to Lake Erie?

A. No.

Q. Then what became of it? Where did it go?

A. It is in Lake Huron-Michigan.

Q. Still?

A. It may be.

Q. Well, then, you do not agree with Mr. Russell's increment, is that right, or his equation?

A. Mr. Russell's increment is based upon the observations which he used in there, and I think that that could be enough in error to account for this difference.

Q. How much in error would it have to be, Professor?

A. Less than ½ of 1 per cent of the discharge.

Q. How about the increment?

A. Let me correct that last statement there. That would be 4 per cent. It would be nearly 40 per cent for the increment.

Q. The discharges would be in error 4 per cent and the increment 40 per cent?

A. Yes.

Q. How much evaporation do you think there is from Lake Erie per year?

A. From Lake Erie?

Q. Yes.

A. I think Mr. Wheeler's paper gives very satisfactory values on that question.

Q. Is that Eben S. Wheeler?

A. Yes. For 1903 you asked for the evaporation from Lake Erie?

Q. Yes.

A. He gives as the mean annual evaporation 26.1 inches.

Q. Well, how much do you think that varies from year to year?

A. Oh, it might vary 20 per cent.

Q. You say might vary? What is the probable variation?

A. You see that depends on so many conditions.

Q. What is the chief factor promoting or influencing evaporation?

A. Why the principal factors are temperature and wind and the humidity of the atmosphere.

Q. What is the chief factor?

A. (No response.)

Q. Temperature is generally considered the chief factor, isn't it?

A. Temperature is the large factor. It was just a question in my mind which was the larger of the two, this humidity or the temperature.

Q. You say that temperature of the water is the chief factor?

A. Yes, I should say the temperature was the chief factor.

Q. What is the evaporation from Michigan-Huron?

A. As given by Mr. Wheeler's observations, or his deductions rather, from the Lake Huron-Michigan Basin, the mean annual evaporation was 20.56.

Q. The Ontario Basin?

A. For the Ontario Basin 23.82.

Q. His investigations of the evaporation for the Huron and Ontario Basin were equally as accurate as those for Erie, St. Clair and Erie Basin?

A. I should say so.

Q. Assuming that there was an excess of 8,000 cubic feet per second more water delivered to Erie in the earlier period, that is from 1860 to 1883, than in the later period from 1890 to 1901, inclusive, as shown by the previous computation, assuming that it was disposed of by evaporation, how much evaporation does this represent on Lake Erie?

A. About three inches, I should say. It would be a case of taking time to compute it.

Q. Then, as I understand it, your conclusion, Professor, is that the evaporation from Lake Erie is about the same as the evaporation from Huron and Ontario?

A. It is a little greater, according to these figures.

Q. Any substantially greater is it?

A. Why, these means give Erie as 2.3 inches greater per year than Ontario; and 5.5 inches greater on Erie than on Huron-Michigan.

Q. Do you agree that failure of the increments of St. Clair and Niagara to check—I refer to the increments deduced by the Lake Survey under their equations of 1912—should be ascribed to a greater evaporation on Erie, or do you consider that the St. Clair increment is too large and should be reduced in order to check with the Niagara increment?

A. I should attribute it to both.

Q. Then when you say that the 8,000 cubic feet of water per second, or the 8,600 cubic feet of water per second, that did not get to Erie, that is not entirely true, is it? Wouldn't

you say some of it might have gotten there and evaporated?

A. Yes, I admit that.

Q. That is possible?

A. Yes.

Q. What is the effect of cold upon oil?

A. Cold?

Q. You use oil in your meters, don't you?

A. Yes.

Q. What is the effect of cold upon oil as used in those meters?

A. It thickens it.

Q. If a meter were freshly oiled and used in water at say 33 degrees Fahrenheit temperature, would or would not the cold water cause the oil to affect the rotation of the propeller?

A. To a very small extent.

Q. Have you ever made any experiments to determine to what extent?

A. Why, that matter would be told by rating—by comparison of rating of meter when it was rated in the summer time with when it was rated in the winter time.

Q. And a meter under these conditions would register less accurately and too low, wouldn't it?

A. To the extent of any effect that that might have.

Q. Did you ever make any tests? You say that you might determine what the effect would be. Did you ever make any tests of your meter to determine that proposition?

A. That particular point, no.

Q. Would a variation of the amount of oil used between moving parts make a difference in the registration in cold water?

A. No, I don't think so.

Q. What provision, if any, is made to ensure the same amount of oil on the meter shaft during the observations?

A. We always aim to put in enough oil to fill the space between the shaft and its bearings, that is the whole chamber, so that after the wheel is put back in place, oil fills the whole space.

Q. How much of a variation have you known or observed in a meter's registration in a single day?

A. I do not quite see the point of that question. The only test that I know of is that one made by Mr. Shenehon, and which he gives in his report on the Niagara River. Yesterday, when testifying, I had forgotten about that test.

Q. Was that in the report on the Preservation of Niagara Falls?

A. No, my recollection is it is in his report on the discharge measurements at the International Bridge.

Q. That was the early measurements?

A. Yes.

Q. Is that the early measurements?

A. Yes.

Q. When did Professor Shenehon make those tests?

A. While making the discharge measurements from the International Bridge.

Q. That was in 1897, was it, or 1898?

A. 1898-1899.

Q. Do you know what tests he made?

A. It was the comparing of two meters.

Q. Did he make a correction for that?

A. In his discharge work?

Q. In his computations, yes.

A. Why, naturally so. The point was to determine everything that had any bearing on the accuracy of the results, and apply it if it warranted.

Q. That is he did make a correction for those variations, diurnal or daily variations?

A. I think so, although I am not absolutely positive. It is some time since I—

Q. You think he should have done it if he did not?

A. Yes, if it warranted it.

Q. How large a variation have you heard of?

A. I think he speaks of about 2 per cent.

Q. About 2 per cent?

A. About 2 per cent.

Q. Do you know how Mr. Shenehon determined that this difference was due to the meter?

A. By comparing two meters.

Q. Might it not be that instead of correcting the meter he would be correcting the velocity, the actual velocity of the river, and that the meter was right and Mr. Shenehon was wrong?

A. Oh, I should not think so.

Q. It depended largely upon the personal equation, didn't it?

A. Yes.

Q. How is the change detected when the meters are in use, say six to eight hours a day?

A. They begin to skip in the registrations.

Q. What is the area of the circle swept through by the wheel of a Haskell A or B meter, in inches?

A. The area of the circle?

Q. Yes.

A. Those wheels are 7½ inches in diameter.

Q. Approximately what would be the area?

A. About 44 square inches approximately. My recollection is it is a little over that.

Q. In gaging the Niagara River at the International Bridge Section, how great an area of the stream actually came in contact with the meter blades? It would be infinitesimal, would it not?

A. Why, yes; it would be small, yes.

Q. And the same answer would apply to the co-efficient work, wouldn't it?

A. Well, it would be larger. It would be ten times as much or eleven times as much.

Q. It would be larger, but still it would be infinitesimal?

A. It would be small.

Q. Referring to the meter and weir test at Philadelphia, do you think the city engineers could have been more particular in their calibration of the weir than Professor Schoder has been at the Cornell Hydraulic Laboratory?

A. I think they made more observations at Philadelphia.

Q. How many more measurements?

A. I could not state the number.

Q. With what did they compare the weir?

A. At Philadelphia?

Q. To establish its rating?

A. I don't know.

Q. Did they compare it with anything, do you know?

A. Why, I suppose—I take it that they constructed a weir which represented as nearly as possible the Francis Sharp Crested Weir.

Q. You don't know about that, do you?

A. I don't know anything about it further than what is in the report which was made.

Q. Where is that report?

A. It is published in a paper of the Engineers Club of Philadelphia.

Q. What page?

A. July to September, 1897, beginning on page 107.

Q. How does the Susquehanna at Binghamton compare with the Niagara at the Split Section as to size?

A. I am not familiar with the Susquehanna at Binghamton, except in a general way.

Q. In a general way as you know it?

A. It is very much shallower.

Q. Is it wider?

A. No, I should say it was narrower.

Q. How much?

A. Oh, it would be a mere guess on my part. I should say it was not more than half the width.

Q. Do you know what the width of the Split Section was, or the width of the river at the Split Section?

A. I don't recall the figures.

Q. Wasn't the Wickwire Section about 2,200 feet, and the Oakfield Section about 1,900 feet?

A. I don't remember.

Q. Or vice versa?

A. I don't remember those figures.

Q. Assuming that to be correct, how much narrower would you say the Susquehanna is at Binghamton than the Niagara River at the Split Section?

A. I should not say it was over half the width of either one of those channels.

Q. Either one? Then probably 1,000 feet wide, something like that?

A. That is a mere guess on my part.

Q. A mere guess. It may be smaller than that?

A. Yes, it may be smaller than that.

Q. May be a little greater?

A. Yes.

Q. Would it be more or less difficult to gage the Susquehanna at Binghamton than the Niagara at Split Section?

A. More or less difficult?

Q. Yes.

A. Really there would be no difference as far as that goes.

Q. As to time?

A. As to the time it was required?

Q. Yes.

A. Oh, really there would be no difference. That is it would take less time to gage the Susquehanna.

Q. That is there would be less verticals?

A. Fewer stations, fewer vertical curves.

Q. And take less time to make the discharge measurements, too, wouldn't it?

A. Yes.

Q. Well, what percentage would you say of time, getting things down to percentage?

A. It would be in proportion to the number of stations.

Q. Well, say about a quarter of the time?

A. Oh, I would not put it in that way. It would depend entirely upon the number of stations. The time required for the observations at a particular station would be substantially the same in each instance.

Q. If it were deeper water, it would take a little longer, wouldn't it?

A. A little, but that would be very small.

Q. Are you familiar with the Drainage Channel, Mr. Haskell?

A. The Drainage Channel here in Chicago?

Q. Here in Chicago, yes.

A. I have been down it; know it in a general way.

Q. Do you know in general how that channel is constructed? It is an artificial channel, isn't it?

A. It is an artificial channel, yes.

Q. Do you know something about the rock section?

A. Why, I know there is a rock section on it.

Q. With comparatively smooth sides and smooth bottom?

A. Yes.

Q. And for a great number of miles it is perfectly straight, is it not?

A. I believe so.

Q. Do you know what the velocity of the current in that channel would be with a flow of about 7,000 cubic feet per second?

A. Why, no. It would be a matter to be computed after getting the figures.

Q. You don't know whether it would be approximately a foot and three-quarters per second?

A. Oh, I don't know. It depends.

Q. Did you examine Mr. Moore's work?

A. No, I did not. I did not pay any attention to it.

Q. You say it is possible to measure the flow of the Niagara River, the St. Clair and St. Lawrence Rivers within ½ of 1 per cent of accuracy?

A. That is to determine the center of gravity. That is provided you are willing to put in the necessary amount of labor.

Q. You are assuming the work that has been done by the Lake Survey, aren't you?

A. Yes.

Q. Would it be your opinion that one could measure more accurately the discharge of the Drainage Channel than the discharge of the Niagara River for instance?

A. Why, I should think they would be substantially the same. The Drainage Canal, of course, would be the easier stream to gage.

Q. Well, how much more accurately could the discharge of the Drainage Channel be measured than the discharge of the Niagara River, say?

A. I should say with equal accuracy.

Q. Well, would the conditions be better or worse on the Niagara River than on the Drainage Channel?

A. They would be worse. It would take more time, more labor.

Q. On the Niagara River?

A. Yes.

Q. Was there less opportunity for errors on the Drainage Canal than there is on the Niagara River?

A. Undoubtedly.

Q. Then assuming all those conditions, wouldn't you naturally say that you could measure more accurately the actual discharge of the Drainage Channel than the Niagara River?

A. No, I should put it wholly on the ground of the amount of labor you are willing to put on each stream.

Q. To overcome the difference?

A. To overcome the difference.

Q. And you have taken into consideration in that the fact that the Drainage Channel is regular in cross section, no disturbance, and that the Niagara River is a river which has very high velocity, about 5½ feet per second or more, and there are obstructions in the river in the shape of bridge piers and so forth at the Gaging Section?

A. Yes.

Q. And you are assuming also that all these difficulties which were mentioned that would be encountered on the Niagara River would be overcome?

A. Overcome by the extra amount of work you would naturally put on it if you wish it to reach the same accuracy.

Q. That is, one would naturally put on?

A. Yes.

Q. Assuming also that in the work on the Drainage Channel you would put on all the work that one naturally would?

A. Yes, all that was necessary to derive all of the coefficients.

Q. The same care and so forth?

A. Same care.

Q. Now, Mr. Haskell, you have given certain values to the increment of the Niagara, St. Clair and St. Lawrence Rivers. You have also stated the effect, your opinion on the effect on lake levels of a diversion at Chicago.

A. Yes.

Q. And you have given certain opinions as to the discharges of the different rivers?

A. Yes.

Q. Has your conclusion in regard to that been based entirely upon the records of discharge measurements in those different rivers and the records of the gage readings as made by the Lake Survey and referred to in this case?

A. It has.

Q. You stated in your direct examination that the rainfall evaporation absorption of the run-off in the drainage basin of the lakes or the inflow from the St. Marys River are neither increased nor decreased by the diversion at Chicago. You stated that in your direct examination earlier in this case, I think on February 17, 1909.

A. Yes.

Q. What do you mean by that statement, Mr. Haskell?

A. I do not see that has anything to do with the question of the diversion at Chicago or vice versa.

Q. Upon what do you base that statement?

A. The rainfall, evaporation and absorption of the run-off of the drainage basins of the lakes or the inflow from the St. Marys River, increased or decreased by the diversion at Chicago, I do not see any relation between the two at all.

Q. That is you do not think the run-off would be decreased by the diversion at Chicago?

A. No.

Q. Or that the rainfall would be increased?

A. Would have nothing to do with the rainfall.

Q. What do you think determines the amount of rainfall on the St. Lawrence basin?

A. The amount of rainfall?

Q. Yes, and run-off. I assume that your answer to the question put there would require a consideration of that question or problem?

A. No, not at all. I do not see that it has any bearing on the problem at all.

Q. But the question was asked here, as I remember it: "Was the rainfall, evaporation, absorption of the run-off in

the drainage basin of the lakes, or the inflow from the St. Marys River increased or decreased by the diversion at Chicago?" Now, wouldn't you, in answering that question—you answered "neither"—have to take into consideration the question or the problem as to how the amount of rainfall on the drainage basin is determined, or what effects it?

A. Why, the fact that you are diverting water at Chicago has nothing to do with rainfall, or nothing to do with evaporation.

Q. What I am trying to get at is how you figure that out?

A. I don't see any point to the question, Mr. Adcock.

Q. I presume that the water that flows down into the ocean gets back on the land some way, doesn't it?

A. It certainly comes back to give us our rainfall.

Q. In the shape of precipitation?

A. Certainly.

Q. And that varies from year to year to some extent?

A. Yes.

Q. And your proposition is it would not be affected in any way by the diversion?

A. I do not see that it has any bearing at all.

Q. Now, you have been a member of the International Waterways Commission for some time, haven't you?

A. Since 1906, the summer.

Q. And they have made several reports, two reports on the regulation of Lake Erie?

A. Yes.

Q. You believe, don't you, Mr. Haskell, that with the expenditure of comparatively a small amount of money the levels of Lake Erie may be raised or regulated?

A. To the extent set forth in that report.

Q. And without injuring, materially injuring anyone?

A. To that extent, as given there.

Q. And that the raising of the levels of Erie would affect the levels of Michigan-Huron?

A. Yes.

Q. And they would be raised?

A. To a small extent. The figures are given for that in that report.

Q. And Lake St. Clair, and the water levels of the St. Clair River, Detroit River and their channels would be raised an intermediate amount?

A. Yes.

Q. The Gut Dam has had the effect of raising the level of Ontario, hasn't it?

A. It has.

Q. Have any series of current meter measurements been made in large streams by anyone other than the Lake Survey?

A. The Mississippi River Commission has been engaged upon the discharge measurements of the Mississippi, Ohio, Tennessee, Cumberland and other streams ever since 1879.

Q. Has any consistent claim ever been made by anyone who made measurements of streams with current meters that the accuracy of the measurements were within ½ of 1 per cent of the actual discharge, except the Lake Survey?

A. No, I don't know that there has; but don't understand me as saying that you could gage the Mississippi with that precision, for the Mississippi River is an entirely different problem.

Q. Well, there are other rivers, aren't there, besides the Mississippi?

A. Yes, sir.

Q. And gaging work has been done on other rivers besides the Mississippi and the St. Clair and Niagara and St. Lawrence Rivers?

A. Yes.

Q. And streams also?

A. Yes, sir.

Q. With reference to those other rivers, has anyone ever made or claimed that they had determined the discharge by current meter measurements of rivers gaged within ½ of 1 per cent?

A. Not so far as I know.

Q. They do not usually make a claim of accuracy of more than 10 per cent, do they?

A. Seldom if ever made any claim at all.

Q. Except the Lake Survey?

A. They never make any claim at all. I don't know of any piece of work to which the care was given that the gaging of the lake outlets was given.

Q. I presume the measurements have been made of streams in rivers other than the St. Clair and Niagara and St. Lawrence and Detroit Rivers, and the St. Marys River, the persons making the measurements desiring to obtain the actual discharge, the law of the discharge of that river as accurately as they could do so and use the natural methods, the natural care, would they not?

Mr. Hopkins: I object to that as argumentative; and an

assumption based upon nothing in this record, unless he knows of the case?

Q. (Question read.)

A. I don't know of any case where there has been an attempt to determine the accuracy that was desired in the case of the work of the survey of the lake outlet.

Mr. Adcock: Q. Well, in measuring the rivers other than the ones I have mentioned, they would not do the work carelessly, would they?

A. Oh, no.

Q. They would use the natural care?

A. Certainly.

Q. And that care which would naturally occur to one who was experienced in that kind of work?

A. Yes.

Q. Now, you spoke of 3 per cent error in the discharge in the St. Lawrence River as determined by the Lake Survey. What is that due to?

A. That is, I think, we know the discharge of the St. Lawrence within the limits of the observations.

Q. Within 3 per cent?

A. I mean by that the center of gravity of those positions within 3 per cent.

Q. Why do you say 3 per cent of accuracy for the St. Lawrence and ½ of 1 per cent for the Niagara River?

A. There was a great deal more work done on the Niagara and the observations there cover a much greater range.

Q. We are speaking of the range of the observations in each case, the center of gravity?

A. Yes.

Q. Did you consider in this connection the perturbation that has been spoken of by persons who made discharge measurements of the St. Lawrence River, this perturbation being at the bottom of the river, in determining this 3 per cent of accuracy of those measurements?

A. I don't think there is any perturbation on the Three Point Section.

Q. At the bottom?

A. At the bottom.

Q. What investigations have you made to determine that?

A. I have not made any myself; just a case of the records.

Q. That is the records of the Lake Survey?

A. Records of the Lake Survey; the soundings that were made in that locality, and the general configuration of the stream.

Q. Assume that there was considerable perturbation at the bottom of the St. Lawrence River, what would you say as to the effect of that perturbation upon the determination of the discharge?

A. Why, it would have to be very large to be appreciable in the discharge.

Q. What comparison have you made in the discharges with the current meter, discharge measurements made with the current meter in smooth flowing water, as compared with those in perturbed and fast moving water?

A. None.

Q. Then upon what do you base the statement that it would take a large perturbation, in order to have any effect upon the discharge or the validity of value of the discharge measurements?

A. We base the accuracy with which we can gage a stream upon such work as that in the Niagara where, for instance, we had the Bridge Section and the Open Section.

Q. You base that entirely upon the check?

A. Upon the check.

Q. Between the two sections?

A. Between the two sections.

Q. In the particular river?

A. In the particular river.

Q. Did you have the difference in velocity, the probable difference in velocity between that of the Drainage Channel and that of the Niagara River when you stated that the Niagara River could be measured, the discharge of the Niagara River could be measured as accurately as the discharge of the Drainage Channel?

A. Yes.

Q. In other words, it would not make any particular difference how great the velocity was?

A. Oh, yes; the velocity could be so high that it would be out of the question to use the meter in it at all.

Q. What would be the limit?

A. Why, really, when the velocity goes above 7 or 8 feet per second, it becomes a very difficult matter to use a current meter in deep water.

Q. And that even with the Haskell Meter?

A. No difference what the meter was.

Q. How about the Price Meter?

A. It would not make any difference.

Q. The Price Meter would not operate as well, would it, at high velocity?

A. The Price Meter is a good meter under certain conditions; an excellent one, under certain conditions.

Q. Do you consider the Haskell Meter will operate better under all conditions?

A. That is the result of my experience, Mr. Adcock.

Q. You say that George Y. Wisner was with you at the time that you looked over the gaging section at the Niagara River?

A. That is my recollection of the matter.

Q. He was not then connected with the Sanitary District in any way?

A. It was not this Mr. Wisnor. That is this Mr. Wisner's father.

Q. And he never was connected with the Sanitary District to your knowledge, was he?

A. No so far as I recall.

Q. In your direct examination you read from a pamphlet which was marked Haskell's Exhibit 2, February 3, 1914, entitled: "Ritchie-Haskell direction-current meter and the Haskell current meters. Instructions in their use by E. E. Haskell, C. E. E. S. Ritchie & Sons, Brookline, Massachusetts, Manufacturers. Washington, D. C. Gibson Brothers, Printers and Bookbinders, 1892." What I have just read appearing on the front page?

A. Yes.

Q. That pamphlet was distributed by E. S. Ritchie & Sons, Brookline, Massachusetts, manufacturers of the Haskell Meters, is that correct?

A. E. S. Ritchie & Sons and myself.

Q. What did you have to do with the circulation of that pamphlet?

A. One of them was given to each purchaser of a meter.

Q. This is a pamphlet which was used by you and the Ritchie Company in connection with the sale and use of the meter?

A. Yes; to give purchasers instructions as to how to use them, how to rate them.

Q. I presume the Ritchie Company issued other papers or advertising matter, didn't it?

A. They issued a small catalog, regular sales catalog, giving a description of the meters and the price.

Q. How long has Professor Schoder been connected with Cornell University, the Engineering Department?

A. Ever since I have been there, and for a few years

previous. I don't know just the date of his graduation. Mr. Williams will recall that.

Q. Probably about 1902, wasn't it?

A. He came there as a student in 1902, according to Mr. Williams' statement.

Q. Professor Schoder has had charge of the hydraulic laboratory at Cornell University since 1904, has he not; and under the title of Assistant Professor of Civil Engineering?

A. No.

Q. What was his title?

A. His title when I went there was that of Engineer in Charge, I think, of the hydraulic laboratory.

Q. What is his title now?

A. Assistant Professor of the College of Civil Engineering.

Q. He has moved up some since then, has he; he had been promoted?

A. He has received one promotion since then.

Q. Do you take part in any of the experiments made at the hydraulic laboratory at Cornell University?

A. It is seldom, if ever, that I do.

Q. Are you ever there when experiments are being made?

A. Yes.

Q. How often?

A. Oh, frequently.

Q. Well, how many times a month?

A. Why, there are certain times when we are making no observations whatever, so far as experiments are concerned.

Q. Well, how many times a year?

A. That is, as a rule, I am at the laboratory say two or three times a week.

Q. And you observed Professor Schoder's work there, you do observe it, do you?

A. I have seen it going on.

Q. You have observed it since 1906?

A. Since I went there in 1906.

Q. You have also observed the work of Professor Turner, haven't you?

A. Yes, Professor Turner has been assistant largely to Doctor Schoder.

Q. How long has he been there?

A. He has been there since 1906.

Q. Now, under what conditions are experiments made by Cornell University in hydraulics?

A. In hydraulics?

Q. Yes.

A. A request comes from a person or company or corporation asking for certain experiments to be made; and those are usually turned over to Professor Schoder and to Professor Turner to work out. I haven't the time that I can devote to it.

Q. And they have made a great many experiments in hydraulics in that laboratory since 1906, have they not?

A. Oh, no; not a great many.

Q. Well, several?

A. Yes, several would fit it. We have only had a very few problems.

Q. They made experiments in connection with their school work there, too, didn't they?

A. Well, that would come under the head of instruction.

Q. But they make experiments for the benefit of the different classes?

A. Certainly.

Q. In hydraulics?

A. Certainly.

Q. Did you ever calibrate the weir by which the water was measured that passes through the canal at the hydraulic laboratory?

A. No.

Q. Do you know who has calibrated that weir?

A. Doctor Schoder and Professor Turner have made some observations upon it.

Q. Don't you know that Mr. Gardner S. Williams calibrated the weir when he was there?

A. That weir has been entirely rebuilt since Mr. Williams was there.

Q. The lower weir?

A. Lower weir, both of them. We rebuilt both of them in 1908.

Q. What changes were made?

A. The main change has been made in the baffles.

Q. How far are the baffles from the lower weir?

A. From the lower weir?

Q. Yes.

A. Which ones do you refer to, which baffles?

Q. The lower end of the canal?

A. From the lower weir to the first baffle is 326½ feet.

Q. What was it before?

A. The same.

Q. How are the baffles changed?

A. The baffles in there now are made up of planks running horizontally.

Q. How were they arranged before?

A. Vertically.

Q. When?

A. I found them that way when I went there. I don't know when they were put in.

Q. How would that affect the discharge over the lower weir?

A. Really would have no appreciable effect upon that.

Q. Then the baffles would have nothing to do, or the location or the form of the baffles would have nothing to do with the calibration of the weir?

A. Not of that particular weir.

Q. The water that went over the lower weir was the same amount as that that went over the upper weir, was it not, in that canal?

A. Certainly.

Q. So, if you knew how much went over the lower weir, you would know how much went over the upper weir?

A. Over the upper weir.

Q. Did you ever go over the experiments made in connection with the calibration of the lower weir or the upper weir?

A. No, I have not.

Q. Then you would hardly be in a position to express an opinion as to whether or not that weir had been calibrated carefully and accurately, would you?

A. Just from general observation, the way I see work done around the University, around the laboratory.

Q. That is in general?

A. In general.

Q. What do you mean by in general? You mean that the work of the particular persons who had to do with the calibration of the weir—

A. Not that altogether, but general conditions.

Q. What conditions? I don't understand.

A. Our canal is not in first class shape for experimental work.

Q. You mean the weirs or the canal itself? I am speaking of the calibration of the weir?

A. Yes.

Q. You stated in your direct examination that the calibration of that weir was 3 or 4 per cent off?

A. No.

Q. Three per cent?
A. From two to three, I think I said.
Q. More than three, didn't you?
A. No.
Q. Two to 3 per cent? Well, upon what do you base that statement?
A. My recollection of the matter is that the standard weir was calibrated by comparison with a small weir in the laboratory, and not by comparison with the lower weir on the canal.
Q. How would that affect the calibration of the weir, the lower weir or the upper weir?
A. The canal in the laboratory is a small one and the water in getting in there has to pass through a gate where there is some obstruction to its free flow.
Q. Did you consider the various formulæ which you mentioned yesterday, various weir formulæ, in arriving at your conclusion that the calibration of the weir might be 2 to 3 per cent off?
A. I usually think of the Francis formula as the standard one.
Q. You didn't use any of the other formulæ?
A. No.
Q. Did you use the Francis formula? That is in arriving at your conclusion?
A. No, that statement is based upon the general care with which I have seen work done around the laboratory.
Q. Then you would not advise people to ask the University to make any experiments in hydraulics?
A. It would depend upon what they were.
Q. That is if they wanted accurate work done?
A. I should want to know whether we could meet the requirements or not, certainly.
Q. You say that your opinion as to the calibration of the weir is that it is 2 or 3 per cent inaccurate, and you base that conclusion upon the general work of the University, general conditions there?
A. No, not of the University.
Q. I assume the general conditions would apply to other tests which you have made or to other apparatus which the University might have there, with which to make experiments?
A. The amount of apparatus which we have there for making experiments is comparatively small.
Q. Well, do you consider that Mr. Schoder and Mr. Tur-

ner are not competent to make experiments in the laboratory, with the apparatus which you have?

A. That they are not competent?

Q. Yes.

A. Oh, no; no.

Q. You don't know any reason why Professor Schoder or Professor Turner would desire to color any experiments that they might make, one way or the other?

A. Oh, no; I should not say that; we—

Q. You have always been on good terms with Professor Schoder and Professor Turner?

A. Certainly, so far as I know.

Q. And they have a high opinion of you and you of them, haven't you?

A. I could not state their opinion of me.

Q. So far as you know, then; a high opinion of you and you have a high opinion of them?

A. Yes, I regard them as two excellent young men.

Q. You have no reason to believe that they would desire in the course of any experiments with the Haskell Meter to in any way carry on the experiments inaccurately, or in a manner which would injure you or the Haskell Meter?

A. Oh, no; I should not accuse them for a moment of any such intent.

Q. What did you mean, Professor, when you said in your direct examination that they were inclined to lay everything on to the meter, all mistakes to the meter?

A. Well, that point, that they assumed a higher accuracy for the measurements over the weir than I think they can justly claim. And I should certainly want to see the observations before I would be fully convinced of that matter.

Q. And you would like to see the observations and also see the work in connection with the calibrations, the experiments with the calibrations of the weir, before you would like to express an opinion as to the accuracy of Professor Schoder and Professor Turner's experiments with the current meter in that canal, wouldn't you?

A. Certainly.

Q. And you haven't seen those up to the present time?

A. I have not seen them at all; no.

Q. You do not believe, Professor, that Professor Schoder and Professor Turner would lay any inaccuracies to the meter if they did not honestly believe that it was due the meter, the Haskell Meter?

A. Oh, no; oh, no.

Q. You think the Haskell Meter presents a cure for most all difficulties that arise in connection with the determination of a discharge of rivers or streams?

A. I do not like the word "cure."

Q. Well, panacea, or something like that?

A. I think it is as good a meter as can be found on the market today.

Recess to 7:00 p. m.

After Recess 7:00 p. m.

EUGENE E. HASKELL resumed the stand and testified further as follows:

Re-direct Examination by Mr. Hopkins.

Q. Mr. Haskell, do you regard Mr. Schoder and Mr. Turner as having had sufficient experience in the matter of current meter work to make tests of the meters such as they testified to, with a high degree of accuracy?

A. No; I should not.

Q. You were asked yesterday as to certain weir tests made by various authors. Do you yourself have any personal knowledge of those tests?

A. No; I have not.

Q. What is the source of your knowledge in regard to those tests?

A. The reading of the reports made upon them.

Q. You were asked as to whether or not a change in the supply of water into the Great Lakes in an earlier period, say 1860 to 1883, compared with a later period. Do you want to make any further statements in regard to that?

Mr. Adcock: He made certain answers with reference to questions along that line. Do you want to add that?

Mr. Hopkins: Yes.

Mr. Adcock: Ask him if he wants to make any change in his answers to that?

A. Will you read that question?

Q. (Question read.)

Mr. Hopkins: Q. Do you want to make any additions or changes to the answers which you made to that question and similar questions?

A. Why, I might possibly describe it a little more fully.

Q. I wish you would.

A. For instance, the gage records beginning with 1860 and continuing up to about 1872 or 1873, are not as reliable as they are since that period. That was a matter that when General Comstock took charge of the survey in 1870, he went into with considerable care, and from about the time mentioned gage records were taken and preserved with greater care than previous to that time.

Q. Now, with regard to the supply of the Great Lakes, do you think cultivation and deforestation has anything to do with it?

A. Certainly, deforestation and cultivation, and increases in use of water for domestic purposes, such as sprinkling of lawns, and possible geologic changes may have some effect upon it, and it is probable that the dredging operations that have gone on have had a small effect upon it.

Q. Upon the levels of the lakes?

A. Upon the levels of the lakes. And undoubtedly there has been some change in the regimen of the various rivers that would have a small effect upon their stage.

Q. To what extent?

A. It would be a very small extent.

Q. Can you give it to us in tenths of feet, an outside limit?

A. Oh, I should say a quarter of a foot.

Mr. Adcock: What is that, the dredging?

Mr. Hopkins: Change in regimen.

The Witness: It may be that the dredging has caused that much of a change.

Q. Now, when you said that the equations in the 1912 report for St. Clair might be applicable to a prior period of 1860 to 1883, with what precision, do you think they are applicable with the earlier period, and why?

Mr. Adcock: Do you mean accurate instead of applicable?

Mr. Hopkins: Applicable; with what degree of precision are they applicable?

Mr. Adcock: I think that is an unintelligible question. I think the witness is entitled to have a question propounded to him that is intelligible.

Mr. Hopkins: Q. Do you understand my question, Mr. Haskell?

A. I would like to have it read to me.

Q. (Question read.)

A. I should think there might be differences of 10 to 15

per cent due to possible changes which I have mentioned, and of which we really have no direct measure.

Q. You mean in the increment, Mr. Haskell?

A. Yes, sir.

Mr. Adcock: Q. How about the discharge at the mean elevation during those periods?

A. For those periods?

Q. Yes.

A. I should think it would be somewhat questionable during that period of 1860 to about 1872 that I spoke of, an accurate knowledge of the stages of the lakes during that period.

Mr. Hopkins: That could be within 3 or 4 per cent, though, couldn't it?

A. Why, I think so.

Mr. Adcock: Q. Assuming you had an accurate knowledge of the stage, how accurately would you know the discharge?

A. Within the range of the observations, I should think then we knew it with the precision substantially which I have stated before.

Mr. Adcock: Half of 1 per cent?

Mr. Hopkins: Q. That does not take into consideration any change in regimen?

A. No; I did not consider that raised in that question.

Q. Mr. Haskell, you were asked yesterday as to whether or not you knew of any tests whereby the velocity of water at the surface could be compared with the water six inches or a foot below the surface?

A. Yes, sir.

Q. Has your recollection been refreshed as to any such tests?

A. Yes; I recall since testifying yesterday those observations made in the Detroit River by coloring the water for the purpose of testing the accuracy of the meters.

Q. That would be a way of testing it?

A. That would be a way of testing it.

Mr. Adcock: Q. Was that in tidal streams?

A. No, not in tidal streams, the Detroit River.

Mr. Hopkins: Q. In speaking of the ice in the Niagara River, you stated that there was no ice to amount to anything above the Falls. Do you wish to qualify or explain that answer?

A. Why, if I said the Falls yesterday, I meant above the Rapids, which approach the Falls.

Q. Now, as to the ice effect in the Niagara River as affecting the discharge of the river, in comparison with the St. Clair River, what is your opinion?

A. The ice effect in the Niagara River is of short duration. I don't know of any case where it extends over but a very short interval.

Q. What do you mean by a short interval, Mr. Haskell?

A. A week.

Q. You were asked as to the effect of cold water or cold temperature in general upon oil? When you took measurements in cold water were your ratings made in the same season of the year?

A. Why, as a general rule.

Q. And what kind of oil was used in your meter?

A. We used watch oil, a special grade that was made for cold weather.

Q. You were asked a number of hypothetical questions, assuming certain ranges and discharge measurements within a degree of accuracy given as to what percentage of error there would be in the difference of discharge. And then you were asked the question as to what percentage of error an increment would have based upon those same assumptions. You answered that the percentage of error of the increment would be the same percentage as the error in the difference between those discharges. Do you wish to make any correction of that answer now? You understand my question, Mr. Haskell? Did you catch my question?

A. Yes, I think so.

Q. All right, answer it?

A. I had thought since thinking the matter over that I misunderstood that question yesterday, and I should state that the error in the increment would be equal to the error in the difference divided by the range.

Q. You were asked certain questions in regard to a report of 1904, in which Mr. Russell made a report which appears in the appendix. I wish you would refer to that report, Mr. Haskell. Just how many pages of that report does that article of Mr. Russell's take up?

A. I believe there are 60 odd pages of it.

Q. When was the last time you read it?

A. I don't think I have read in since it was published.

Q. Did you ever study it with any great care?

A. Oh, I read it, of course, before it was published, and read it over quite carefully at that time.

Q. Now referring to the conclusions reached by Mr. Russell beginning on page—

A. Of the summary here, on page 4129.

Q. 4129. Before I ask that question: When you say you approved of it, just what does that mean, Mr. Haskell?

A. Why it means that I considered the report worth publishing.

Q. Does it mean that you agreed with the conclusions reached in there?

A. No, not necessarily with all of them, but that I did feel there was data in it to make it worth while to publish it.

Q. Now referring to the summary just referred to, on page 4129, is it?

A. 4129.

Q. Will you go through those summaries and tell us if there are any that you disagree with, which you did not mention today; and if you do not recall which ones you mentioned today, go through them all and tell which ones you disagree with. Take Number 2.

A. In regard to Number 2, I do not feel that we know the laws governing the flow of the Detroit River accurately enough to say that the formula which Mr. Russell derived here is an entirely satisfactory one.

Q. Number 3.

A. In Number 3, Mr. Russell states that the height of the water surface of Lake St. Clair in relation to heights of Lakes Huron and Erie is given by a certain equation there, in which he gives the co-efficient of the first term as .602. It is my understanding that later observations have increased that to .66.

Q. Go ahead and point out any others?

A. I think I spoke about, in fact, I am sure I spoke of Number 4 today.

Mr. Adcock: You refer to certain qualifications in 4 that you had not noticed when you made your first answer?

A. Mr. Russell makes a statement there, and then he qualifies it, and I should agree with his qualification.

Mr. Hopkins: All right, take Number 5.

A. The value of C in the Chezy formula there which Mr. Russell gives, I should regard that as questionable.

Q. How was the Chezy formula made up, in the first place, Mr. Haskell?

A. It is an empirical formula. The constant C is dependent upon observations to determine it.

Q. How about the work of measuring rivers in the Lake Survey, with reference to determining formulae of its own?

A. That has been a primary object in all of the Lake Survey work, was to make a determination of all of the coefficients needed for the reduction of the work.

Q. And would you regard those experiments just as accurate as the application of some such formula as the Chezy formula?

A. I should be inclined to say more so.

Q. Now continue as to the summaries.

A. I see no objection whatever to 6. I should question 7.

Mr. Adcock: What does that relate to?

A. Mr. Russell states, "The difference of 4,700 cubic feet per second adopted in the datum discharges of the St. Clair and Detroit Rivers is derived by taking it to be a part of the discharge of the Niagara River proportional to the Lake St. Clair drainage area as compared with the whole drainage area of the lakes above Niagara River." I should hardly hold that it was applicable. I see nothing in 8 to disagree with. I see nothing in 9 to question. I should not agree with 10.

Mr. Adcock: What does that relate to?

A. That relates to substantially the same thing that is set forth in 7, with which I did not agree.

Mr. Hopkins: Q. And 11 is dependent upon 10, isn't it?

A. Yes, 11 is dependent upon 10.

Mr. Adcock: Q. What does that have reference to, same thing?

A. Substantially the same thing, Mr. Adcock.

Q. You mean you question his mathematics or you question his assumption?

A. Question his assumptions.

Q. Of course, the mathematics is all right?

A. The mathematics, there are no question about.

Q. From my understanding, Mr. Russell is a very good mathematician?

A. He is an excellent mathematician, splendid computer.

Q. But you do not agree with all of his hydraulic conclusions?

A. No, there are very few of us that do agree on all these fine points.

Mr. Hopkins: Q. With reference to Number 11, do you consider the result reached by Mr. Russell as too high or too low, that .6 run-off?

A. I should say it was too high.

Mr. Adcock: What, per square mile?

A. Per square mile. This is the rainfall, reference to rainfall, [illegible] of the rainfall.

Q. Does not refer to the run-off?

A. Does not refer to the run-off per square mile; 12 is a little questionable, I should think.

Mr. Hopkins: Q. In what respect, Mr. Haskell?

A. That is he states there that "the adopted datum discharges for the St. Clair and Detroit Rivers are possibly too large and the discharge of the Niagara too small by very considerable quantities." I should not be inclined to put quite so much emphasis on the quantities. I should agree substantially with 13 and with 14.

Q. Where do you think the error in 15 would be more likely placed?

A. I am not willing to express an opinion in regard to that. I have some doubts about it.

Q. Take 16.

A. 16 is correct.

Q. Take 17.

A. I could not agree with 17.

Q. In what respect?

A. I think the quantity which he states as .8 of a foot is too great; 18 is unimportant in regard to this case.

Q. 19?

A. I should have no occasion to question 19.

Q. Now 20, take that.

A. I don't think Mr. Russell's statement in regard to 20 is quite correct. I do not see why the rise in Lake Erie for a foot rise in Lake Huron if continued should not be substantially the same. Nothing to question in 21; that is just purely a case of mathematics.

Q. How about the exact values as given in 22?

A. I made a statement in regard to those today. They are substantially correct. They are a little low for Erie. I think in my original testimony I answered that question and gave a little higher value than is here given for Erie; 23 is substantially correct. In regard to 24, I should not care to make any statement. That would be merely a question of computations.

Mr. Adcock: You would assume the computations were made correctly by Mr. Russell?

A. Unquestionably his computations are right. That is the data with which he started might be a little different from what I should use, if I were to go into the problem. In re-

gard to 25, Mr. Russell, in speaking of evaporation there, I should agree with those conclusions, and I think the figure which he gives for the evaporation from Lake Superior agrees very closely. Mr. Wheeler's figures are smaller than that by about four inches; and Mr. Russell's figures for the evaporation on Lakes Michigan-Huron are about approximately an inch greater than that given by Mr. Wheeler. In 27, I should question again that statement of .6 of the run-off being .6 of the rainfall, and his statement for evaporation is nearly ten inches higher than that given by Mr. Wheeler, which I would question.

Q. For what lake is that?

A. For Lake Erie. That is all in Mr. Russell's conclusions that have any bearing on the question.

Mr. Hopkins: Q. Mr. Haskell, in your direct examination you said that for Mr. Schoder to get an accurate measurement of the Susquehanna River, you thought it would take about a month. What did you take into consideration in giving that opinion?

A. I took into question the determining of all of the co-efficients, that is, the measuring of the vertical curves for all of the current meter stations, and going through the regular process of deriving all of the co-efficients that entered into the problem.

Mr. Adcock: Q. Was this with the Haskell meter?

A. Does not make any difference.

Mr. Hopkins: Q. Is that considering his experience and his equipment?

A. Certainly.

Q. I believe you said that the stream was at low stage at that time. Would that make a difference?

A. It would make a little difference.

Q. In a shallow wide stream would there be a different problem than in a deeper stream?

A. Why we have the feeling that we can get better results in a stream of reasonable depth than in one where it is so shallow that you practically have to wade it to do anything.

Q. And in getting at the precision of measurements in a shallow stream the percentage of the volume that is nearer bottom is greater, too, isn't it?

A. The friction on the bottom of course amounts to more. It is a larger percentage.

Re-cross Examination by Mr. Adcock.

Q. For what purpose are the contributions by the Lake Survey made in the Engineer's Reports?

A. I do not understand your question exactly, but the point of this investigation, of course, was made in the interest of navigation.

Q. Yes, but a lot of things are published in the Engineers' Reports from year to year, reports are made by the Lake Survey are they not?

A. Yes.

Q. What is the purpose of publishing those reports?

A. For the purpose of putting before the people concerned the data that has been gathered up to that time.

Q. One of the duties of the Principal Assistant Engineer, is it not, is to pass upon the reports prepared by Engineers in the office of the Lake Survey, as to whether those reports should or should not be published?

A. Certainly.

Q. Of course, the Principal Assistant Engineer brings to the office which he holds his experience and knowledge that he has gained in long years of work in the Lake Survey, doesn't he?

A. Certainly.

Q. And he determines what reports are accurate and are of value, does he not?

A. He does.

Q. Isn't it the purpose to present conclusions in such reports which are accurate, and to which the Principal Assistant Engineer subscribed?

A. That is the purpose.

Q. And it certainly is not the purpose to publish inaccurate statements of work done, or inaccurate or improper conclusions made from experiments or work done by the Lake Survey?

A. No.

Q. With reference to conclusion 20, in Mr. Russell's report as follows: "A rise of 1 foot in Lake Huron if continued would eventually produce a rise .727 foot in Lake Erie," I understood you to say it would produce a rise of 1 foot in Erie?

A. I should say approximately 1 foot.

Q. Then you would disagree with Mr. Russell's report in that connection?

A. In that connection.

Q. Do you know how deep the Susquehanna River is at Binghamton?

A. Only by hearsay.

Q. You stated in your cross-examination that you didn't

know, but that you thought it was shallower than the Split Section of the Niagara?

A. I should say that just simply from general information of the river, that is all.

Q. So you don't know whether the Susquehanna can be waded at Binghamton?

A. No, I would not make any positive statement in regard to that.

Q. If that impression might be gained from your re-direct examination, you wish to correct it in that regard?

A. I wish to correct it, certainly, because I have had nothing to do—

Q. Now this Chezy formula, that is a formula which is considered as a standard formula, isn't it, used by all hydraulic engineers?

A. Yes, it has been used very extensively.

Q. And no one has ever questioned the accuracy of that formula, have they, as representing approximately the results?

A. Oh, no.

Q. What experiments did you make with this oil that was used?

A. What experiments?

Q. Yes.

A. None. We adopted that oil because the makers of it claimed that temperature had little effect upon it. It was a brand of oil which they made—

Q. You accepted the statement?

A. It was a brand of oil which they make especially for timepieces that are to be carried in cold climates.

Q. You accepted the representations made by the seller?

A. Certainly.

Q. What effect does deforestation have? You mentioned some effect in your re-direct examination. I did not understand whether it was to increase the supply of water or to decrease it.

A. That is where the timber is cut off.

Q. Then the cultivation of various areas of land, too, you mentioned?

A. Yes, where the timber is cut off, of course water gets to the streams more rapidly, and evaporation becomes a more important factor than it does in a timber country. The same is true of cultivated land.

Q. Then you think the lakes would probably be at a higher

level than during the period when the forests were upon the different areas?

A. At a higher level now?

Q. Yes.

A. No, I should say if anything the reverse.

Q. The deforestation and cultivation of the large areas of land would have the effect of decreasing the amount of water that would go into the lake proper?

A. No, it would bring about a different distribution; that is the time at which the water reached the lake would be earlier, for instance, than in the case where the country was timbered.

Q. When is the usual high water time during the year?

A. You see, that varies in the different lakes.

Q. Well, take Michigan-Huron, that is a pretty good example?

A. High water in Michigan-Huron comes the latter part of June.

Q. About the beginning of navigation, a little after the beginning of navigation?

A. After the beginning of navigation.

Q. You think it would probably under these new conditions be a little bit earlier than June?

A. That is, the tendency would be for it to come earlier.

Q. Very much, do you think?

A. Why, it is hard to say. We really haven't any data. Theoretically it looks as if that would be the case, but we haven't data sufficient to make an absolute solution of it and say that it is so.

Q. You spoke of the inaccuracies of gage readings during the earlier period, say along from 1860 to 1873, or '74, as I remember it?

A. Yes.

Q. How much would you say the mean of the gage readings from 1860 to 1883 was likely to be in error?

A. From 1860 to 1880?

Q. 1883.

A. 1883. Oh, in the mean it might be possible to be in error between 1-10 and 2-10 of a foot.

Q. Do you think Mr. Schoder and Mr. Turner had had more or less experience in current meter work and hydraulic work than Mr. Shenehon had had when he took charge of the measurements, discharge measurements of the Niagara River at the Bridge Section?

A. I should say less.

Q. They had had less or that Mr. Shenehon has had less?

A. No, Mr. Schoder had less.

Q. You have read Mr. Schoder's and Mr. Turner's testimony, have you not?

A. Why, yes, I read it through.

Q. I believe Mr. Shenehon had been on the gaging work of the St. Marys River at the Spry Dock Section, hadn't he?

A. Yes.

Q. That was the only work he had done before he commenced on the Niagara?

A. That is, as far as my recollection goes.

Q. That is true?

A. That is true.

Q. One of the difficulties in getting an increment, isn't it, Professor, is the connecting a discharge measurement to the proper stage of the lake, or to the stage of the lake that corresponds to the condition of the river at the gaging section when the discharge measurement is made?

A. No, that is not difficult at all.

Q. That is one difficulty you have, isn't it?

A. One difficulty?

Q. Yes.

A. I don't look upon that as a difficulty. That is we refer the discharge measurements usually to a gage at the section or close by the section, and if we want to transfer it to some other locality, we make the transfer by gage relations.

Q. But you take an interval of time, don't you, between the gage at say the controlling point and the time when you make your discharge measurement?

A. No, you can make them entirely independent of that.

Q. How was it done on the Niagara River? Was there any transfer of gages there?

A. I think in the case of the Niagara River they did determine the time interval between a rise for instance on the Buffalo Gage, and the rise on the gage at the section.

Q. And that was about eight minutes, wasn't it, time interval?

A. Why, something like that; just about eight minutes, I think, as stated in the report.

Q. But if you could take the measurement say of the discharge, 100 measurements of the discharge of the Niagara River when Lake Erie was at a constant stage, say 572, running over a period of several days, and you could also take 100 discharge measurements of the Niagara River when Lake Erie was at 573, running over a similar period of time, you

would have a better condition, you could determine the increment better for such measurements than you could from a number of measurements running over the same range of stage where the meter was at intermediate heights, the lake level was at intermediate heights.

A. No, I should not say so.

Q. Would it be just as accurate?

A. The observations which you made under the conditions which you named would have a much smaller range. They would come much closer to the center of gravity or to the true discharge curve.

Q. That is under the conditions which I assumed?

A. Yes.

Q. Than if the dicharge measurements were made when the lake was at a stage intermediate to 572 and 573?

A. Yes, you see a discharge measured on a rising river gives us, as we say, a mean velocity that is too great and on a falling river a mean velocity that is too small, and, of course, our range there becomes greater.

Q. Assuming the conditions which I first mentioned there, would you consider the increment obtained in that way as accurate as an increment which was obtained by a similar number of discharge measurements over the same range of stage where the stage of the lake was changing?

A. Yes, I should.

Q. You stated that the increment derived from the discharge observations of the Niagara River might be in error 2 per cent, didn't you?

A. I think that was my figures.

Q. And you also stated that the error of the difference between the mean discharge at a mean stage of the lake and the mean discharge at another mean stage of the lake would be approximately 10 per cent under conditions assumed in the cross-examination with reference to that subject matter?

A. That it might be possible.

Q. The increment would be ten per cent in error?

A. It might be possible, but hardly likely in the case of Niagara.

Q. Under those conditions?

A. Under those conditions.

Q. Now assume that you had 100 measurements of the discharge of the Niagara River when the lake state was exactly 573, you would know the discharge of the Niagara River within ½ of 1 per cent for that stage, wouldn't you?

A. I should feel that way.

Q. And if you had 100 other measurements made when the lake stage was exactly 572, you would know the discharge at that stage within ½ of 1 per cent, according to your figures?

A. Yes.

Q. What would be the error in the difference between the mean discharge at the elevation 573 and the mean discharge at 572? That is the error of the increment?

A. That is as between those two limits?

Q. Those two points, and assuming 100 observations made—

A. At each point?

Q. Yes, at each point, when the lake stage was exactly at that point?

A. I should say we knew it very closely, indeed.

Q. How closely?

A. Within that half of 1 per cent.

Q. Why do you make a distinction between that case and the other instance, the other comparisons?

A. Because the conditions which you gave are ideal, extreme accuracy for the two points.

Q. You simply have the stage the same, don't you?

A. But you have made 100 observations at each point under ideal conditions so that in that range—that is you must know the form of the curve very closely indeed.

Mr. Hopkins: I do not believe that he understands the question. It is exactly the same question asked yesterday.

Mr. Adcock: I think it is.

Mr. Hopkins: That you asked yesterday, where the difference was given at ten per cent.

Mr. Adcock: Q. How much might it be in error then, Professor Haskell? Might it be in error ten per cent, the increment?

A. In this particular case which you state here?

Q. Yes.

A. I should say no.

Q. How much might it be in error?

Mr. Hopkins: Those 100 observations are taken at absolutely the same point.

Mr. Adcock: Same stage.

Mr. Hopkins: Same stage; and exactly the same question was put yesterday; assuming a degree of accuracy at the mean discharge at a certain stage within ½ of 1 per cent, another discharge at another stage within ½ per cent, what would be the possible percentage of error in the difference given between zero and ten per cent. This is exactly the

same question as I see it, because you have got your 100 readings, understand, Mr. Haskell, at exactly the same point, so that your degree of accuracy of ½ per cent is just the same as the degree of accuracy of the other. If you want to change your whole opinion on the same thing, that is one thing, but it is exactly the same question. You may want to change your whole opinion. (To Mr. Adcock): He may want to change the whole thing.

The Witness: To me, the question is different entirely.

Mr. Hopkins: In both cases they assume a degree of accuracy at one point of ½ per cent. That is where they start from in both cases. All these other furbelows do not,—

The Witness: He states conditions that are absolutely ideal, and says that he has got 100 observations under ideal conditions; no change in stage. That gives him that point at 573, and he makes similar conditions for his 572.

Mr. Adcock: Do you consider you can make a discharge observation more accurately at one stage than at another?

A. No.

Mr. Hopkins: Let it go ahead either way. Mr. Haskell says he wants to read his testimony at more leisure.

Hr. Adcock: Q. Here is the proposition: If he answers one way, I am going to lead up to another question.

Mr. Hopkins: Go ahead.

Mr. Adcock: If his answer stands.

Mr. Hopkins: He may want to change it. My point was it seemed to me it was the same question, but if he thinks it is different all right; he is testifying, not me.

Mr. Adcock: Q. You would give greater weight to a series of observations made, of continuous observations made when the lake level was more or less at an even stage, would you, Mr. Haskell?

A. No. The resulting observations, as I stated before, would show a less range.

Q. I am taking a range of 1 foot here?

A. Yes, and your statement, the conditions which you supposed were substantially the fixing of those two points with an absolute certainty.

Q. If you had a series of observations made say when the lake stage was approximately 572, and several of them, and a series of observations made when the lake stage was approximately 573, or another elevation, you would give more weight to those observations than you would to a similar number of observations made when the lake stage, lake level was at a

stage intermediate to 572 or 573 as the case might be, wouldn't you?

A. No.

Q. Then as I understand it you give more weight to observations made running over a period of several days when the lake stage is exactly at 572 or at an even stage than you would to observations made when the lake stage was changing, but at some mean? The mean of the lake stage being the same for the last series of observations.

A. (No response.)

Q. Assuming that there were the same number of observations in each series and running over the same period of time?

A. Observations which were taken at a time when the lake was at a uniform stage and remained that way, of course, we would get a smaller range in our observations and they would be taken under more ideal conditions and the tendency would be to give them greater weight than the others.

Q. You would be closer to the true discharge, wouldn't you?

A. Those individual observations would be closer to the true discharge.

Q. The mean of the several observations taken would be nearer accurate than the others, is that correct?

A. Substantially so.

Q. And an increment derived under conditions where the lake level was more or less at an even stage would be more accurate you think than an increment derived from discharge measurements where the lake was changing around, assuming the same variation between mean elevation of the two centers of gravity used?

A. Yes.

Q. Suppose that you took 50 pairs of discharge observations and derived an increment from each of the 50 pairs and then took the mean of the increment derived from those 50 pairs, what would be the accuracy of the resulting increment?

A. That to my mind gets right back to the other condition of affairs.

Q. Well, what do you think would be the percentage of accuracy?

A. It might be anywhere between zero and say 10 per cent.

Q. Take 100 pairs?

A. It would not make any difference. That is, we would have the feeling that the 100 pairs would get a little closer to the truth. The more the observations, why—

Q. How much closer, in percentage?
A. In percentage?
Q. Yes. Or what would be the percentage of error in that case?
A. In the case of 100 pairs?
Q. Yes.
A. I should think we were getting very close to ½ of 1 per cent; that is on the true positions of the points of the centers of gravity.
Q. And the increment? I am asking about the increment, percentage of accuracy of the increment?
A. I should say it might be anywhere within the limits, as I have stated before, of zero and say ten per cent.
Q. Suppose you had 25 pairs?
A. I should say we did not know it as accurately.
Q. Within what percentage of error?
A. Your statement was 25 pairs?
Q. Yes.
A. Twenty-five pairs, that is getting down to a small number of observations to fix anything of that kind.
Q. What do you think it would be?
A. Oh, it might be ten per cent, may be more.
Q. Then it does not make a great lot of difference whether you have 10, 25, 50 or 100 pairs of observations?
A. Certainly it does.
Q. I thought you gave substantially the same percentage of error?
A. No. I may have given substantially the same for your 50 or your 100; that is in the first place you have got 100 observations fixing a certain point. At another stage, you stated that you had another 100 observations. That ought to fix those points very accurately.
Q. I am speaking now, Mr. Haskell, of taking 100 pairs and deriving an increment from each pair?
A. From each individual pair?
Q. Yes.
A. Oh.
Q. And then taking the mean of the increments thus derived?
A. Oh, that, I should want to see the observations before I expressed an opinion about that.
Q. Assuming they were made by the Lake Survey and assume in that connection that the observations composing the pair were not less than .5 of a foot apart, as far as lake stage is concerned?

A. I think you would fall into a greater error.

Q. How much?

Mr. Hopkins: I shall move to strike out all of this examination on the same grounds given before, that it is not re-cross examination. We have not gone into it at all?

Mr. Adcock: Is that a warning, or a protestation?

Mr. Hopkins: Simply that it may appear.

The Witness: That is the increments taken at equal intervals ½ a foot apart?

Mr. Adcock: We assume that no pair is used where the observations are closer together than ½ foot in elevation?

A. Closer together?

Q. No pair is used where the observations are closer together than ½ foot in elevation. That is purely an assumption.

A. Any answer that I make would be more or less of a guess.

Q. If it is not too much trouble, Mr. Haskell, I would like to have your opinion as to that. I appreciate we have had a long day.

A. You wanted that in percentage?

Q. Yes, what would be the percentage of error of the increment thus obtained, if any?

A. It might be within the same limits.

Q. Assuming 25 pairs, Mr. Haskell?

A. 25 pairs?

Q. Yes.

A. The limit certainly indicated would be greater.

Q. It might be some more than 10 per cent?

A. Yes, might be double that.

Q. What would the probable error be under each condition, with the 100 pairs?

A. The probable error with 100 pairs?

Q. Yes.

A. Why, you would have to have the observations to work that out.

Q. Assume you had observations made by the Lake Survey covering range, stage, say a foot and a half, each pair not being less than a foot and half apart?

A. You have got to have the observations themselves before you can make out a probable error.

Q. What do you think probably would be the error of the increment?

A. You are referring now to the 25 pairs?

Q. No, to the 100 pairs.

A. I should say it might be anywhere within the limits of zero to 10 per cent.

Q. But probably, what would the error probably be?

A. Oh, say half of that.

Q. Then for 50 pairs, you would have the same answer, would you?

A. Of course, theoretically it would be a little greater than that.

Q. But not appreciably. Practically it would not amount to much?

A. Why, it would depend upon the observations; might not amount to anything.

Q. Then 25 pairs?

A. When you begin to cut down your observations, of course you haven't got the position of your line determined as well.

Q. Now take all the observations that have been made by the Lake Survey as to the discharge of the Niagara River and the increment which they have derived, what do you consider to be the possible error, what might the error be of the increment that has been derived for the Niagara River, 21,-900 cubic feet?

A. The possible increment?

Q. The possible error of that increment, what might it be?

A. I certainly don't believe it could be greater than 5 per cent.

Mr. Hopkins: How many, all the observations?

Mr. Adcock: All the observations made by the Lake Survey upon the Niagara River as to the discharge of the Niagara River; what do you think might be the error of the increment derived from those discharge measurements?

A. I should say 5 per cent.

Mr. Adcock: I think that is all.

Adjourned subject to notice.

CHARLES Y. DIXON, a witness called in rebuttal on behalf of the Government, was first duly sworn and testified as follows:

Direct Examination by Mr. Hopkins.

Q. State your full name?
A. Charles Y. Dixon.
Q. What is your business?
A. Civil Engineer.
Q. By whom employed?
A. United States Government, under the War Department.
Q. Will you just give us your training, education and experience in your line of work?
A. I graduated from the University of Michigan in 1887, in the prescribed course in Civil Engineering. I was in railroad work for 3 or 4 years; and began work with the government under the Engineer Corps, River and Harbor Improvement at the Soo, in 1892. In 1896 I was transferred under the same office to the Detroit River work; and I have been located in Detroit and vicinity ever since.
Q. In a general way, what has been the nature of your work connected with the United States Government in the river mentioned?
A. The preparation of specifications and making of surveys with the idea of improvement of channels.
Q. How long have you been at work on the Detroit River?
A. 18 years.
Q. Will you just tell us in detail what work has been done by the United States Government in the Detroit River?
A. Since I have been here?
Q. Do you know the work before you came here?
A. I know it as a matter of record.
Q. Well, give us all of it.
A. The first channel improvement on the Detroit River was made in 1877 at Lime Kiln Crossing; and until 1890 it was carried on, not every season, but as the money was appropriated; it was not continuous; but in 1890 the project at Lime Kiln Crossing, that they had in mind, was completed for a width of 440 feet. Later on a more general project was adopted, and work has been continuous since 1892 on the De-

troit River at different localities; not of course all in one place.

Q. What was the work done in 1870 at the Lime Kiln Crossing, what result was accomplished?

A. That of course was before my connection with it.

Q. I understand.

A. The original depth there was about 12½ to 13 feet, but the work that they did under those contracts, (there were several of them) provided for a depth of about 18½ feet at the midsummer stage which prevailed at that time. And the general average face of excavation, average depth of material removed, was perhaps about 2½ to 3 feet over the area that was improved at that time.

The length of the channel improved was about 2500 feet, and 440 feet wide, to the maximum face say about 6 feet.

Q. What was the nature of the excavation?

A. At that point it was rock.

Q. Was it rock?

A. Yes.

Q. Loose or in place?

A. There were a few overlying boulders.

Mr. Adcock: That was in 1870?

A. I am speaking of the work that was done prior to my going there. It is a mere matter of record. There were a few loose boulders overlying the bottom, but the matrial was mainly rock in place.

Q. What was done with the material?

A. It was deposited in the river. The greater part of the material that was excavated prior to 1890 was deposited just below but to the west of Stony Island; that is below Stony Island but a little bit west of Stony Island.

Q. What was the depth of the water in which the material was deposited?

A. About 12 feet generally, and the depth over the dumping ground as left would be from 4 to 5 feet. It would be very irregular however.

Q. Originally, was there any current in this channel where the material was deposited?

A. Yes, some.

Q. How about since that deposit?

A. There is still a perceptible current there.

Q. What effect did that depositing of material have upon the current?

A. Well, it would reduce the cross section at that point, of course.

Q. Did it have a compensating effect as far as the lowering of Lake St. Clair is concerned?

A. It did, yes.

Q. Now coming on down later, you say there was quite a little excavation about 1890. Just where and what was that?

A. In 1892, I think the work was resumed again at Ballard's Reef. From then for several years, there was work done in that locality.

Q. What was the nature of that work?

A. That was mainly rock, although in places there was earth and boulders overlying the rock to a depth of 2 or 3 feet; in some places more, but generally rock in place had to be removed in order to secure the improvements.

Q. Some of that work you say was in boulders and fragments of rock?

A. Yes.

Q. And what was done with the material?

A. Most of the material taken out of Ballard's Reef was deposited along the eastern shore of Grosse Isle; that would be north of Stony Island.

Q. Did that depositing of material have a compensating effect upon Lake St. Clair?

A. It tended to obstruct the flow in the river, yes.

Q. That was the purpose of depositing it there?

A. The purpose of depositing it was to get rid of it of course.

Mr. Austrian: I do not think you ought to put quite every answer in the witness' mouth.

The Witness (continuing): The material of course was excavated and we had to get rid of it, but in the depositing of material, the dumping grounds were so selected as to compensate as largely as we could for the excavation, and of course we had to be governed by the depth of water that was available, too. We could not always select perhaps the point that would compensate the most; but we had that in mind in choosing the dumping grounds.

Q. Any subsequent work that was done?

A. The work following that work at Ballard's Reef?

Q. Yes?

A. Well the work at Ballard's Reef was completed in 1899, the original project. Later on another project was adopted for an increased depth that required the entire area

to be gone over again and deepened about a foot and a half or two feet more.

Mr. Adcock: When was that?

A. That was started along about 1902, and in fact that project is not yet completed. It is completed with the exception of a little work at Ballard's Reef which is now nearing completion.

Q. What was done with the material in those cases?

A. It was deposited in the same general localities as I have indicated.

Q. Is there any other work that you have not mentioned?

A. The Livingstone Channel I have not mentioned.

Q. Go ahead with that?

A. That project was adopted in 1907, and the work of excavation was started in 1908; and the Livingstone Channel was completed and opened to navigation in 1912. This route is a straight channel, leaving the old channel at Ballard's Reef, and going straight to the mouth of the river, to the Detroit River. Light house, at the mouth of the river, going to the west Bois Blanc Island. It is 300 feet wide through the greater part of its length in the river. At the mouth of the river it widens to 800 feet. In the 300 feet portion, the material is mainly rock. There was a length however that was surrounded by dams and excavated in the dry, and that portion of the channel instead of being 300 feet wide is 450 feet wide. That is opposite Stony Island.

Q. In that case, was the material deposited in the river?

A. It was, excepting some of the material that was excavated in the dry, that was dumped off in piles on each side, and subsequently some of it has been taken to Detroit and crushed for commercial purposes. It has been excavated with a dredge. They are removing all the material that is there.

Q. Is there any other dredging in the Detroit River that you have not mentioned?

A. I think I have covered it.

Q. What effect has all of this dredging had upon navigation?

A. It has increased the navigable depth from what it was originally at Lime Kiln Crossing, about 12½ feet, as the records show to, at the present time a depth of about 19½ to 20 feet. In the Detroit River, there would be 21 feet navigable depth, if it were available elsewhere.

Q. Through the whole length of the Detroit River?

A. Yes, sir.

Q. Has there been any other material dumped into the Detroit River, other than that you have mentioned as being dredged in the river itself?

A. Well, there has been some excavation here in Detroit that has been deposited in the river, but it does not amount to a great deal. It is only a small amount.

Q. How about the river Rouge?

A. Yes, there has been excavation in the river Rouge and also excavations for buildings in Detroit; I believe some of that was taken down the river.

Q. Do you know how much was excavated in the river Rouge and dumped in the Detroit River?

A. No, I could not tell you that.

Q. What is your opinion as to the effect of all this work in the Detroit River upon the level of Lake St. Clair?

Mr. Adcock: Objected to.

Mr. Hopkins: If you object to the form of the question I will change it. I will withdraw that question.

Q. Has any other work been done in the Detroit River to compensate for that dredging?

A. A portion of the material that was excavated in channel improvement was, as I briefly stated, deposited so as to form a dam to surround a portion of the channel area, which was excavated in the dry. Those dams, of course, served to compensate. In those dams, an excavation has been made through them for the channel, of course, which is 300 feet wide, the dams have been removed for an opening of about 380 feet.

Q. How long were the dams themselves?

A. The area enclosed by dams was about 5800 feet long and about 1500 or 1600 feet wide.

Q. What is the length of the dam crossways of the current?

A. It would be about 1200 feet perhaps abreast of Stony Island.

Q. Do you have an opinion as to what effect all of this work in the Detroit River has had upon the elevation of Lake St. Clair?

A. I have an opinion, yes.

Q. What is that opinion?

A. Well, I do not think our improvements have affected the level there any more than to the extent of 1/10th of a foot anyway; not more than that.

Mr. Austrian: Q. Up or down?

A. It may be lowered perhaps 1/10th.

Mr. Hopkins: Q What are the ice conditions in the Detroit River?

A. The ice occasionally forms dams at the head of Fighting Island, and also at the head of Grosse Isle on the main Michigan shore, and at the head of Bois Blanc Island on the Canadian shore, in the narrower portions of the channel.

Q. How about ice cover?

A. The river in a severe winter is usually covered from Detroit to Lake Erie with ice; the ice being anywhere from a six inches thick to a foot and a half foot, in places.

Q. What effect does that have upon the volume of flow?

A. It retards it.

Q. How frequently does that sealing over of the river occur?

A. Well, we have not had it this year, and we had it last year only for a short time. Last winter was very mild, as it has been this winter; but with the ordinary winter the river is covered with ice, perhaps about six weeks I should say.

Q. What has been your experience in soundings?

A. In carrying on our work, we have made surveys every year during my work for the Government, for the past twenty odd years.

Q. With what degree of precision can you make soundings as for instance when you are trying to determine the area of a cross section?

A. I should say within 1 per cent. I would expect more accuracy in earth bottom than in a rock bottom. In rocky bottom, it is more or less uneven.

Q. What depth of water do you refer to?

A. I am speaking of depths of water from perhaps 15 to 25 feet. That is what I had in mind.

Q. And a current such as in the rivers you have mentioned?

A. Yes, sir.

Mr. Austrian: What rivers?

Mr. Hopkins: He has been speaking of the Detroit river and the other rivers which they mentioned, which happened to be the St. Marys or the Soo.

Q. A current such as the Detroit River, I will put it?

A. Yes, sir I had that in mind.

Recess to 2:30 P. M.

After Recess 2:30 P. M.

CHARLES Y. DIXON, resumed the stand and testified further as follows:

Mr. Hopkins: Q. Will you explain further your answer in regard to the degree of precision that you can get in soundings?

A. Our work in making surveys has been in depths of water ranging generally from 10 to 25 feet. In such depths, and in the current in the Detroit River, I would expect to get within 1/10th of a foot at least of the accurate depth.

Q. In 20 feet of water, what precision would that be as a percentage?

A. Well, that would be 1/10th of the difference, 1/2 of 1 per cent.

Q. How would it be in 30 feet of water?

A. I would expect within a tenth of a foot.

Q. So that your percentage in that case would be 1/3rd of 1 per cent.?

A. Yes, sir.

Mr. Hopkins: That is all.

Cross-examination reserved.

Depositions in the above entitled cause, taken pursuant to notice, before the Commissioner, at the Lake Survey Offices, Detroit, Michigan, commencing on Tuesday, February 17, 1914, at 11:00 A. M.

Present:

Mr. Albert L. Hopkins, representing the Government.
Mr. Edmund D. Adcock, representing the Sanitary District.

CHARLES Y. DIXON, recalled for further examination testified as follows:

Cross-Examination by Mr. Adcock.

Q. Prior to 1905, Mr. Dixon, who determined where the spoil coming from excavations, should be dumped; speaking of the channel in the lower Detroit River?

A. Between 1896 and 1905, I did that, mainly at least; it was approved by the Engineer Officer in charge, always.

Q. It was on your recommendation, was it not?

A. Usually, yes, sir.

Q. Where was that spoil usually dumped with reference to the excavation area?

A. In what particular?

Q. As near the place where it was excavated as possible?

A. Yes, we usually tried to avoid a long haul to the dumping ground.

Q. What calculations did you make to determine where the spoil should be dumped?

A. You wish me to state how we arrived at the locality?

Q. Yes?

A. As to the dumping ground?

Q. Yes?

A. Well, we inspected the chart to determine the locality of available depth where it would not interfere with probable future improvements, or be objected to by property owners on shore, of course having in mind the compensation of the dumping ground, also.

Q. What calculations did you make to determine the compensation effect, if any?

A. We made none at that time.

Q. That is prior to 1905?

A. Yes.

Q. Since 1905, who determined where the spoil should be placed?

A. The same way.

Q. And you followed the same method?

A. Same method.

Q. In what depth of water was the spoil usually dumped?

A. Usually not less than 10 or 12 feet. That would be governed by the amount of water that the loaded dump scows would draw.

Q. That was the determining factor was it?

A. Largely, yes, sir. That would vary with the contractor's plant.

Q. You have done considerable sounding?

A. We have, yes, sir.

Q. To get a precision of, say one per cent., in the area of a cross section, as testified to by you in your direct examination, how frequent in your judgment should be the sounding?

A. Our soundings are taken at the corners of ten foot squares over most of our work.

Q. That is ten feet apart?

A. Ten feet apart, both ways.

Q. That is across the river?

A. Across the river and up and down stream also.

Q. Up and down stream also. Can soundings of the same depth be made more or less accurately in swift flowing than in slow flowing rivers?

A. In slow flowing rivers.

Q. On rock bottoms are abrupt changes of depth of, say one or two feet, likely to occur in the cross section?

A. They are occasionally found, yes, sir; more frequently in rock bottom than in earth bottom.

Q. You spoke of the Livingstone Channel Improvement, the cofferdam, in connection with your direct examination. How much of the material composing the old cofferdam was the contractor authorized to remove?

A. None excepting that which crossed the channel, for a width of—

Q. There has been some controversy, hasn't there, between the government and the contractor as to his right to remove this material?

A. Not the dumped material. That was the excavated material that was piled up on the side of the channel.

Q. I mean the spoil that was piled up there?

A. That matter was referred to the department in Washington, and they decided that the material belonged to the contractors, and they are now engaged in excavating all that material.

Q. Just state what material that is they are now engaged in excavating, taking out?

A. Those are the piles of rock that are on each side of the channel.

Q. That is of the new Livingstone Channel?

A. That is of the new Livingstone Channel, that were deposited there within the cofferdams.

Q. In case all that material is removed, the material that you have mentioned, what effect will that have upon the flow of the river at that point?

A. It would increase the flow slightly, but the area is still surrounded by the original dam and a portion of the dump pile will not be removed, because it is being removed for commercial purposes, and for about a thousand or 1200 feet at the south end of the area where those piles are, there is

considerable earth mixed in with the rock, and there it becomes of no value to them for their purpose.

Q. When this work was finished, was there considerable material that was removed from the Livingstone Channel piled above the surface of the water?

A. Yes, sir, there was.

Q. Of course that would have no compensating effect?

A. No.

Q. What is the depth of the Livingstone Channel now?

A. The clear depth within the dams is 23 feet. Outside of the dams it is 22 feet. The actual depth of excavation is somewhat greater than that.

Q. Do you know about how much that is?

A. Within the dams, it would be something less than a foot greater.

Q. A foot greater?

A. Less than a foot greater. It would vary somewhat. Outside of the dams, it in places would be two and perhaps three feet greater than that.

Q. What would be the depth of the water in the lower Detroit River, testified to by you as having been 12½ or 13 feet; that is originally before excavation was made; having in mind the present elevation of Lake Erie?

A. It would be slightly less than that which you have stated.

Mr. Adcock: That is all.

Re-direct Examination by Mr. Hopkins.

Q. Is any of this material that is being taken away by the contractor above the water level?

A. It is, yes.

Q. What part of it is above the water level?

A. The height of the pile above the water level varies from seven to perhaps 20 feet, and it comes to a point at the top.

Q. How deep are they going below the water?

A. The depth of water where the pile was dumped varies from perhaps about four feet at the least depth to about twelve or thirteen feet at the greatest.

Q. Are they attempting to take it all?

A. They are taking all that they can excavate with a dredge. It is doubtful if they can excavate that which is in the shallowest water. They have not yet done that. In fact,

their operations were stopped at the place of least depth last season.

Q. In your judgment what effect has this taking away of the material by the contractors had upon the compensation work in the river?

A. I think it has very little effect.

Mr. Adcock: Q. That is the material that was taken away up to date?

A. Yes.

Q. At the present time?

A. (No response).

Mr. Hopkins: I think that is all.

Re-re-Cross Examination by Mr. Adcock.

Q. When the material was originally placed there on the side of the Livingstone Channel, it was claimed by the Government, was it not, that the Government owned that material?

A. I understood so. At least it belonged to the contractor during the life of his contract and then reverted to the Government. That was my understanding.

Q. And the Government had the right to designate the place where the material should be dumped?

A. Yes.

Q. Or placed?

A. Yes If you will permit me to explain more fully—

Q. Yes.

A. That question was afterwards referred to the department at Washington, and they decided that the material belonged to the contractor even after the expiration of the contract.

Q. Has the Government taken any steps to purchase the material from the contractor, or acquire it in any way?

A. No.

Re-re-direct Examination by Mr. Hopkins.

Q. When did the contractor start taking away this material?

A. My recollection is early last season.

Q. Did you have that in mind when you testified before that the effect on the level of Lake St. Clair, in your opinion, was not to exceed one-tenth of a foot?

A. I did not take that into consideration at that time. It was our records that I had in mind at that time, they did not cover the—

Q. Now taking into consideration this, what is your opinion as to the effect on the level of Lake St. Clair?

A. I would not change my former testimony.

Further Re-cross Examination by Mr. Adcock.

Q. That is as to the conditions at the present time?

A. Yes, sir.

Q. What calculations have you made, Mr. Dixon, to determine the effect on St. Clair, Lake St. Clair, of the excavation that the Government has made there in the Detroit River?

A. I have made a study of the records of the water levels since the records have been kept; and have made some deductions. Will you permit me to consult my notes on that?

Q. Yes?

A. In making some of these deductions, reference was made to the water levels at Lake Huron, the water gage at Harbor Beach; that of Lake St. Clair at St. Clair Flats Canal, and Lake Erie at Cleveland; and prior to the improvement there were 20 monthly means selected, which agreed nearly with 20 monthly means after 1904, after the greater part of the improvement was made.

Q. Did you follow in that connection substantially the same method that Mr. Ray followed?

A. In this case, yes. The mean of the Lake Huron levels for the first period was 581.45.

Q. What years did you take?

A. I can't give you the months, but they were in the years from 1865 to 1879; 20 of the months. And in making these deductions, the yearly means were taken for the months from May to November inclusive, so as to avoid any obstructions due to ice jams. As I stated, the elevation of Lake Huron for that first period was 581.45.

Q. That is the entire period?

A. For the first 20 months prior to the improvement and for the 20 months after the improvement, the elevation of Lake Huron was 581.37; that is a difference of .08 of a foot.

Q. That is prior to 1879?

A. 581.45 was prior to 1879; 581.37 was after 1904.

In the first period, the fall in the St. Clair River is 5.45

feet; in the Detroit River 3.15 feet, making a total fall between Lakes Huron and Erie of 8.6 feet. After the improvement, the fall in the St. Clair River, that is the difference between the Lake St. Clair and Lake Huron levels, was 5.52, and between Lake St. Clair and Lake Erie 3.07; making a fall between Lake Huron and Lake Erie of 8.59 feet, showing that for corresponding elevations the slope in the two rivers,—tht fall in the two rivers remained practically unchanged; and if there was any change in one stream, there was a corresponding change in the other.

I also made some deductions based upon the areas of the cross sections in the vicinity of Lime Kiln Crossing. The only portion of the stream that has been changed as the result of the improvement is that portion of the channel between Stoney Island and the Canadian Shore.

From the early surveys, as shown on the charts, the cross section of what was called the Lime Kiln Crossing channel prior to the improvement was 47,400 square feet. After the Lime Kiln Crossing improvement and before the Livingstone Channel improvement, the area was 55,300. After the Livingstone Channel Dam was built, the area east of the dam, between that and the Canadian shore, was 37,400, being a change of nearly 18,000 square feet. As the result of the building of that dam, the elevation of Lake St. Clair was raised nearly .3 of a foot. That our records show.

After the Livingstone Channel was opened, the cross section of the two channels then between Stoney Island and the Canadian shore was for the Livingstone Channel 12,000 square feet and for the easterly channel 37,400 square feet as it was before. So that the area of the two channels east of Stoney Island is now about 2,000 square feet greater than it was before there was any improvement at all.

If a change of 18,000 square feet has caused the change in level of .3 of a foot, a change of 2,000 square feet would not be near as great, of course. It was less than one-tenth of a foot. That computation is necessarily only approximate, but it gives results that may be relied upon.

Q. In making the comparison which you mentioned between the 20 months in the two periods, did you take into consideration or compare the precipitation on the Michigan-Huron area and the Erie Basin?

A. No, sir.

Q. Did you make any investigation of the change, if there was any, in the so-called hydraulic radius?

A. No, sir.

Q. How much material was taken out before you began work on the Livingstone Channel? I believe you stated that the cross sectional area was 47,400 square feet, didn't you?

A. Before improving.

Q. What was that?

A. That was before improvement.

Q. After the improvement and before the work on the Livingstone Channel, you say it was 55,300 square feet?

A. That is it, yes, sir.

Q. And about how many yards of material were taken out?

A. In that vicinity, in that stretch of the river?

Q. Yes?

A. I can give it to you only as applied to the contract covering that stretch of the river. There were three contracts covering practically the same stretch of the river, about half a mile long or a little more; and the amount of material removed from that area prior to 1890, was about 112,000 cubic yards.

Later, between 1906 and 1908, under other contracts there was 357,000 cubic yards removed. The work prior to 1890 covered a length of channel of about 2500 feet and a width of 440 feet. That later covered a length of channel of about 4300 feet and a width of 600 feet. The later work consisted in deepening the former channel, and in taking in some additional area.

Q. Have you finished your answer?

A. I have.

Q. Do you consider that there was any lowering effect from these improvements prior to the commencement of the work on the Livingstone Channel?

A. Slightly, I think, yes.

Q. About how much?

A. I would think not to exceed one tenth of a foot. I think we are about back now where we were before; that is the dams of the Livingston Channel raised the water.

Q. I am speaking of the time prior to the work on the Livingstone Channel, was there any effect?

A. I think not to exceed .1 of a foot.

Q. The cross sectional area there was increased about 8,000 square feet, was it not?

A. It was.

Q. And the reduction of that area by the Livingstone Dam by 18,000 feet, they raised it 3/10ths of a foot?

A. Approximately.

Q. How long was the dam in there?

A. The dam was started in 1908 and completed about mid-season of 1909. It was opened so far as the channel area is concerned in July, 1912.

Q. That is the dam was there from 1908 to some time in 1912?

A. That was it.

Q. Well, do you consider that the full effect of the dam would be shown on the St. Clair in that period, three years?

A. I think so.

Q. How about Lake Huron, was there any effect in Lake Huron?

A. The effect on Lake Huron would be somewhat less than on Lake St. Clair.

Q. And would the full effect be shown in change of stage of Huron? Would the full effect be reflected on Huron in three years?

A. I think so.

Q. Has the full effect of removing the dam been shown on these two lakes?

A. I would not want to say as to that. Our records are not complete enough. In fact our records for 1913 have not yet all been reduced.

Q. In your judgment, without reference to the records, what do you say?

A. It might not be entirely felt yet, but I think there would not be much change from now on.

Further Re-direct Examination by Mr. Hopkins.

Q. How long in your opinion would it take the full effect of the removal of the dam to appear in Lake St. Clair?

A. I would not want to state positively. I would expect it to occur in a season nearly, although it might not.

Q. What is the present fall in the river, in the stretch where this excavation work has been done?

A. We have a water gage at about a half mile above the dam, and one on the Canadian shore nearly abreast of the foot of Bois Blanc Island. The fall between those two gages is something like 1.1 feet.

Q. What is the distance in miles there?

A. Something like four miles.

Q. What is the distance between Lake St. Clair and the lower gage?

A. About 23 or 24 miles, something of that kind.

Q. When was the improvement work on the Lime Kiln Crossing resumed after 1890?

A. The first contract—there were two contracts later—the earlier one of those two was completed in 1906. I think it was started in 1904 or 1905.

Q. What amount of material was removed between 1890 and 1905?

A. None at Lime Kiln Crossing.

Further Re-cross Examination by Mr. Adcock.

Q. Did your last answer include the entire lower Detroit River?

A. Just the Lime Kiln Crossing. There was work at Ballards Reef during that interval.

Q. Did you include Ballards Reef?

A. No, I did not.

Q. Was there some work done between 1890 and 1905 near Ballards Reef?

A. Yes, sir.

F. G. RAY, recalled in rebuttal on behalf of the Government, having been previously sworn, testified as follows:

Direct Examination by Mr. Hopkins.

Q. Mr. Ray, you have already testified in this case, haven't you?

A. I have.

Q. When did you testify?

A. I believe that was in the spring of 1909.

Q. Since that time what further experience or qualification have you had in this engineering work?

A. I was promoted to the position of principal assistant engineer with the Lake Survey in the fall of 1909, since which time I have had direct supervision of all field work and office reductions, in connection with the work of the Lake Survey.

Q. Whom did you succeed?

A. Mr. Shenehon.

Q. What was the occasion of your succeeding him?
A. Mr. Shenehon resigned and left the position vacant.
Q. What have been your duties in this new position?
A. I have acted under the direction of an Army Officer and have had, as I stated before, direct supervision of the field work and office reductions, in connection with the work of the Lake Survey; and have outlined field and office work and have prepared instructions under which the different field parties worked.
Q. What experience have you had in observations and in the reduction of observations, during all of your experience?
A. I started in government service with the Mississippi River Commission in 1892. The work on which I was engaged with the Commission was very similar to that of the Lake Survey. In 1901, I was transferred to the Lake Survey and have been employed by them since, and during the entire time have been engaged in field work and office reduction pertaining to the field work. That covers topography, triangulation, hydrography, magnetic observations and various other work of that nature.
Q. In all of that work you have had to do with the reduction and treatment of observations, have you?
A. I have had to do with the reduction and treatment of observations practically since the beginning of that period.
Q. And as to soundings?
A. I have personally had charge of parties engaged in soundings over a period of perhaps 15 years in the aggregate, a part of which time was on the Mississippi River.
Q. About how much time have you been on board ship on the Great Lakes, so that you could observe the conditions of the lakes?
A. I have been on board a vessel continuously during the field season, from 1901 to 1909 inclusive.
Q. How many months make a season?
A. Average of about 6½ to 7 months.
Q. What contact have you had personally with the hydraulics of the Great Lakes and the rivers connected therewith?
A. I had practically no experience in the hydraulics previous to 1909, other than to be familiar with the reports and methods of field work and office reductions, but not directly connected therewith.
Q. How about since 1909?
A. Since 1909, I have had supervision of the field work, including all of the hydraulic work of the Lake Survey.

Q. Since 1909, what has been the work of the Lake Survey, over which you have had supervision?

A. In the late fall of 1909, the hydraulic party was engaged on a measurement of flow in the St. Marys River, and also in the St. Clair River. There was one additional season of hydraulic measurements in 1910, on the St. Clair River.

In 1911, the hydraulic party was engaged on measurements on the St. Lawrence River, and again in 1913. Also in 1913, the Third Section or Split Section in the Niagara River was measured.

Q. What was your personal connection with this work? To what extent did you yourself supervise it, come in contact with it?

A. I drafted the instructions covering this work, usually after conference with the other assistants familiar with the hydraulic work, and with the supervision of field work as it progressed.

Q. Did you visit the work in the field?

A. Frequently.

Q. To what extent did you follow the detail work?

A. I consider that I followed it quite closely; that is as far as I had time consistent with the other duties of the office.

Q. Did you become familiar with the results and conclusions of these observations that were taken under your direction?

A. I did. I followed them very closely.

Q. Have you followed the reduction of the observations?

A. I have.

Q. From all of your experience and knowledge, from whatever source, have you reached a conclusion as to the precision of the work of the Lake Survey during that time?

Mr. Austrian: Objected to unless the witness states what the source of his information is; "Whatever source" must be a source in evidence.

Q. (Question read.) Including, of course, your knowledge of the work to which you have just testified, and if you have had any other knowledge aside from that, tell us what it is?

A. Do I understand you want—

Q. Referring specifically to the St. Clair, the Niagara and the St. Lawrence River measurements?

A. From my knowledge, I judge the hydraulic work on these three rivers to be probably the most accurate measurements in large streams that have ever been done.

The precision of measurement, considering the weighted

mean observation I believe to be within 2 per cent. of the exact result.

Q. Now, referring particularly to the St. Clair River, upon what do you base your opinion?

A. Upon the care with which the work was done, and upon the results that were obtained at three different sections on the river; all of which agree extremely close.

Q. Will you state what those three sections were, and what the conditions were in each one of them?

A. The original section was at Dry Dock, the so-called Dry Dock Section, where the flow was smooth and below the average velocity of most of the measurements that have been taken by the Lake Survey. The Gorge Section at the head of the river had—

Q. First, what was the velocity in the first section you mentioned, roughly?

A. I have in mind about 2 to 3 feet per second; I am not positive.

The Gorge Section was located in the narrow portion of the St. Clair River near its head, and the velocities on this section were practically nearly double those on the Dry Dock Section. The third measurement was taken in the delta at the mouth, and this consisted of six separate streams. The sums of the measurements of these streams were compared with the results obtained at the head of the river.

Q. What was the check between sections?

A. There was no precise method of check between the Dry Dock and Gorge Sections, owing to their being some little difference in stage, and the two lakes, Huron and St. Clair, not being in the same relative elevations, with respect to each other. The centers of gravity of the two sections were very close together however, and indicated a check of about 1 per cent.

Q. Now, as to the Niagara River?

A. I believe the precision of result there, the weighted mean result, is correct within 2 per cent.

Q. What is that based upon?

A. That is based upon the large number of observations that have been taken and the fact that measurements were taken on three separate sections, where the conditions were considerably different.

Q. What was the degree of check between those sections?

A. The check between the Open Section and the Bridge Section was about 1½ per cent. The Third or Split Section fell between these two.

Q. Now as to the St. Lawrence?

A. I believe that the precision with which we know the flow of the St. Lawrence is not as exact as that of the Niagara or St. Clair Rivers, and this is not due to any greater percentage of error in the measurements themselves, but there, so far, has been some little indecision in regard to the stability of the gages.

Q. What is your opinion as to the percentage of error in the St. Lawrence, possible error?

A. The possible error in the weighted mean flow there is in my opinion about 3 per cent.; that is the maximum.

Q. Speaking of the instability of gages, to what gages do you refer? Do you refer to the Ogdensberg gage?

A. I have more in mind the possibility of a change in the conditions at the gages rather than the instability of the gage. There seem to be some slight discrepancies in comparison of the local gages, and particularly the lock gages with reference to the gages on Lake Ontario.

Q. When the readings of observations are referred to the Ogdensburg gage, do you not have rather stable condition or do you?

A. The conditions are seemingly stable, with the possibility of very slight change in the Ogdensburg gage.

Q. Is there enough in that to account for the 3 per cent. of error that you mentioned?

A. No, I consider that the 3 per cent. error includes all sources of error.

Q. You mentioned certain work done in the St. Lawrence in 1913. By whom was that work done?

A. That was done by Mr. Richmond.

Q. Was that done under your direction?

A. It was.

Q. Prior to 1913, by whom was the work that you mentioned done?

A. Mr. Richmond also took measurements on the St. Lawrence River in 1911.

Q. Was that under your direction?

A. It was.

Q. During that work, was the cross section re-determined?

A. It was. It was re-sounded and the horizontal measurement was also checked.

Q. How did that check with the original cross section of Mr. Shenehon?

A. There was practically no difference.

Q. Did they re-determine the vertical curve?

A. They re-determined the vertical curves on certain of the stations in mid-stream, covering a large percentage of the total volume of flow.

Q. How did that check with the vertical curves that were obtained formerly?

A. I don't recall the exact figures, but the check was very close.

Q. All of these measurements by M. Richmond were since the Gut Dam, were they?

A. All of them.

Q. Would that have any effect upon the relation between the elevation at Ogdensburg and the flow at the section measured?

A. It would. The Gut Dam is between Ogdensburg and the Section, so that the relation of the Ogdensburg gage to the discharge measurements would be changed by the construction of that dam.

Q. Does that make the situation more complex?

A. It makes it more complex in attempting to relate the recent measurements to the measurements before the construction of the dam.

Q. Do you have an opinion as to what the increment is, say first of the St. Clair River?

A. The reductions of the St. Clair River measurements, as made under my supervision give an increment of about twenty-one and a half thousand. This is referred to Lake Huron elevation of 580. The formula which we derived was not a straight line formula, so that this increment varies somewhat for the different stages.

Q. In the percentages of error which you have given as to the discharge measurements of the various rivers, on which side, if either would they occur?

A. It would be liable to occur on either side.

Q. It is just as likely to be on one side as on the other?

A. (No response.)

Q. What is your opinion as to the precision of the increment you have just given in the St. Clair?

A. I believe that increment may be in error from 10 to 15 per cent.

Q. On which side?

A. I would believe that, if anything, the error is on the large side.

Q. That is that the real increment is smaller than the one you have given?

A. The real increment is smaller, if anything.

Q. Upon what do you base that, Mr. Ray?

A. More on comparison with the increment of the Niagara than anything else.

Q. Why do you give such a wide degree of error?

A. The St. Clair River is the most difficult to measure and refer to lake stages of any of the rivers connecting or flowing out of the Great Lakes. The reason for that is that the flow depends upon the stages in both Lake Huron and St. Clair. It is practically impossible to cover a very wide range on either lake without the other lake moving with it, and it makes a rather complex problem to separate the backwater increment from Lake St. Clair and the headwater increment for Lake Huron.

Q. Do you think that the true increment is a straight line or a curve, the true line of the increment?

A. I believe the true line is a curve.

Q. And with reference to low stages of the lake, how would the increment be, higher or lower than the increment at mean stages?

A. The increment would be lower on lower stages.

Q. You gave us an increment awhile ago at mean stage of the lake. How many feet were you speaking of then in the stage of the lake? What is the mean stage in other words?

A. The increment that I mentioned was between 580 and 581, referred to the Harbor Beach gage?

Q. Take a lake stage 1 foot lower than that, what do you think the increment would be?

A. In answer to your question, the increment for 1 foot lower stage would be, as I compute it, 20,700; that is in round numbers about 900 less than for the foot above.

Q. That is between 579 and 580?

A. Between 579 and 580.

Q. Now what is the increment of the Niagara River?

A. The discharge formula for the Niagara River as computed by the Lake Survey, the more recently derived formula, is a curve. The increment between stages 569 and 570 on Lake Erie is 19,540, and at the top of the curve, between 574 and 575, it is 23,510.

Q. What is it at elevation 573?

A. About 22,000.

Q. Is that about mean stage, or what is mean stage in feet?

A. Mean stage in feet is 572.55; that is for the 53 years from 1860 to 1912 inclusive.

Q. What is the increment for that stage Mr. Ray, mean?

A. That is almost exactly 22,000.

Q. What is your opinion as to the accuracy of the Niagara River?

A. I believe that increment is correct within 5 per cent.

Q. Why do you give the higher degree of precision to that increment?

A. On account of the small range from that line, from the line which that formula represents; and also for the reason of the large range in stage covered by the observations.

Q. Is that the increment derived at the International Bridge Section?

A. That is.

Q. How close does the increment of the Open Section compare with the one you have given?

A. The increment at the Open Section is, at stage 572.50, 21,720.

Q. The increment at the Open Section is a little lower than that at the Bridge Section?

A. A trifle lower than the increment shown by the Bridge Section.

Q. What is the general condition of the Niagara River itself, with regard to it being favorable or unfavorable for determining the increment with reference to lake stages?

A. I consider that the conditions are extremely favorable, principally on account of the fact that the sections were measured near to the headwater reservoir, and there was practically no backwater effect.

Q. The headwater reservoir you refer to is Lake Erie?

A. Is Lake Erie.

Q. Now what is the increment of the St. Lawrence?

A. The discharge equation derived for the St. Lawrence River by the Lake Survey is also a curved line formula, and has a varying increment. The increment at stage of 243 on the Oswego gage is 21,125, and for a stage of 248 is 25,045.

I wish to say further in regard to the increments just given, that those are derived from a formula which was deduced in the Lake Survey Office in 1912, from all observations taken previous to that time. That did not include the discharge measurements taken during the past season, and as I stated previously, there was some little question in regard to the gages on the St. Lawrence River, and the proper way to relate the discharges to the gages. All measurements taken during this past season seem to indicate that the increments just given are too large. No new reduction has been made to

include the last year's measurements, as it is considered necessary to continue the measurement of flow in this river, to obtain an accurate discharge curve.

Q. What is the degree of precision, in your opinion, of that increment?

A. I believe that the increments that I gave are correct within 10 per cent.

Q. On which side?

A. I believe I have just stated the measurements of the past season seem to indicate that the increments derived from the previous equation are too large.

Q. Is the Niagara the only river in which the increment was determined from measurements at two different sections?

A. The measurements on the St. Clair River were taken at three sections; also three separate sections on the Niagara River.

Q. Do you understand that the increment of the St. Clair was derived from measurement on three different sections?

A. No, I do not. That was derived at the two sections at the head of the river.

Q. In this work which you have testified about of measuring these rivers and deriving the increments, about how many engineers have taken a part in it, particularly in the computations, getting the results to which you have testified?

A. In what period of time? Mr. Moore and Mr. Richmond have both had charge of field parties engaged on hydraulic work, aside from the principal assistant engineer. They have had technical assistants on the work who have helped in the reductions.

Q. About how many technical assistants would they have?

A. Usually only one, that would be considered as an engineer.

Q. Mr. Ray, have you read Mr. Williams' testimony?

A. Practically all of it.

Q. Have you read the part that deals with his method of reduction of the observations?

A. I have.

Q. What is your opinion of that method of computation of observations?

Mr. Austrian: I object to that; that is not a subject that you can call for the conclusion of an expert upon. I submit you can ask him wherein he does not agree with anyone, but you cannot ask him for his conclusions on the result.

(Question withdrawn.)

Q. Do you have any comments to make upon his method of reduction of these observations?

A. I have not checked any of the reductions made by Mr. Williams. The principal thing that attracted my attention in regard to this matter was the use of a long period of time, long periods of lake stage to relate the various observations to.

Q. Just in detail, explain the method you are speaking of now?

A. As I recall, discharge observations on the Niagara River were selected during certain periods. I am not quite clear as to why these periods were selected; and the mean gage during a certain period was related to the discharge measurements, each one being given a certain weight according to the number taken on that day, or according to the number of days between the observations. Where two observations were taken on a day during mid-week, a weight of one-half was given to the observations providing the observations had been taken on the preceding and following days; and in case of Sundays, additional weight was given to the observations taken on Saturday and Monday.

Q. How long does it take the effect—

Mr. Austrian: He has not made any comment upon that method. He has not finished his answer.

Mr. Hopkins: If you want it, we will let him go ahead.

Mr. Austrian: Certainly, I do want it.

Mr. Hopkins: All right, go ahead Mr. Ray.

Mr. Austrian: I want him to finish his answer.

Mr. Hopkins: Q. Go ahead, commenting on the method.

A. I have given this method of reduction some thought since I read the testimony of Mr. Williams, and I fail to see any reason for taking a mean stage during a long period of time, and referring a single observation or a series of observations to this stage. I see no reason for considering that the stage of a previous day has any bearing on the discharge measurement that was taken, for instance on Monday; I see no connection between the Sunday stage and the Monday discharge measurement. The period of time between Lake Erie stages as measured at the Buffalo gage and the stage at the Bridge Section, I believe is about eight minutes.

Q. Any further comments, Mr. Ray?

A. It would seem to me that observations related to mean gage in this manner would on the whole, covering a long period of time, give a close approximation to the relation of the mean stage and the mean discharge covering that time.

But the tendency in that manner of relating the gages and discharges would be to increase the increment. It would tend to smooth out the lake stage and give a smaller range of stage during the observations than the correct one.

Q. When you say would give a greater increment, you mean greater than what?

A. Greater than the true increment.

Q. How much in advance of the observation did Mr. Williams take his gage in hours, at the beginning of a particular period?

A. I have not compared all these. I find the first one I notice is about 36 to 38 hours ahead of the actual observations.

Q. What do you regard as the true time that should have been taken in advance of the observation?

A. I regard as the true time the time in which the observation was taken, corrected by the time interval for a crest of stage to advance from the Buffalo gage to the Section, which I believe is about eight minutes.

Q. What in your judgment is the value of the conclusion reached by referring the observations to a gage 12 hours or 36 hours before, in the particular instance?

A. I cannot conceive that the stage for any considerable period, such as 12 to 36 hours before, has any effect or any bearing on the discharge at the time it was taken.

Q. Would its tendency be to bring error into the reductions or not?

A. As I stated before, the weighted mean discharge for a considerable period related to the mean stage for the same period would be substantially correct in all probability, but the range of stage to which the discharges were related would be considerably smaller than that occurring at the times of the discharges; and the error of this method of measurement in my opinion would tend to increase the increment over the true one.

Q. What is your opinion as to weighting the observations by time interval, where a Sunday intervenes or something of that kind, as it appears in Mr. Williams' testimony?

A. I fail to see any virtue in that method of reduction.

Q. What would be the result of that?

A. I am not quite sure what the result would be. It would depend on the fluctuation of the stage during the discharges. I believe I would have to take specific instances before I would arrive at any conclusion as regards that.

Q. Do you see any impropriety in that method?

A. I must say that I believe it is an incorrect method, if it is intended to derive a correct increment from the data.

Q. Do you understand how many observations Mr. Williams actually used, out of those available in the Niagara River?

A. I did at the time I read the testimony. I have forgotten.

Q. Do you have in mind about what percentage?

A. I do not now.

Q. Do you know whether the 118 observations of 1907 and 1908 were used?

A. I believe not.

Q. What are your views as to the rejection of observations?

A. I do not consider that it is proper to reject observations, except under very extreme cases where they are known positively to be in error.

Q. Are you acquainted with the 219 observations that were made at the Bridge Section?

A. I had nothing to do with making the reductions. I am familiar with the results of the reductions, and familiar with the method of work during the field observations.

Q. Do you know of any reason why any of them should have been rejected, consulting Haskell's Exhibit 1, for Identification, of this date?

A. I know of no reason why any of the observations should be rejected, in deriving the increment or in deriving the volume of the flow.

Q. What is your opinion as to the derivation of an increment by the ratio of fluctuations from one lake to another?

A. I believe that that method of comparing increments would be very good if there was an unobstructed flow between the lakes, and if we knew the relative local supplies to these lakes.

Q. What obstruction if any are in the particular lakes or rivers that we have in mind, that might interfere?

A. The principal obstruction to the flow, considering the flow 12 months in the year, is the ice effect during the winter months.

Q. How would that affect the relative fluctuations between Michigan-Huron and Erie?

A. The relative fluctuation would not bear a direct relation to the increment of flow if the connecting waters were obstructed during a portion of the year. The tendency, in

my opinion would be to raise the upper lake. There would be extra storage in Lakes Michigan and Huron, and also the increment of flow which we have determined for open season conditions would not hold through the winter months and would not represent a mean increment for the 12 month period.

Q. As compared with the method of deriving an increment in, say the St. Clair River, by actual measurement of volume and referring it to a known gage, what is your opinion of the method of deriving an increment from ratio of fluctuations?

A. The increment as determined from measurements of discharge would be far superior in accuracy to any determined by relative fluctuations of the lakes.

Q. What are your reasons for that?

A. There are a great many intangible elements affecting the stage of water in the two lakes, so that it is impossible to determine accurately what the effects of the various causes, such as rainfall, run-off, evaporation and so forth contribute towards the variation of stage.

Q. What is your opinion as to the possibility of accuracy determining the local supply?

A. I would not care to state the degree of accuracy. I think the results obtained by the use of such data would be somewhat inaccurate.

Q. Would it be more in the nature of an estimate than a determination?

A. I think so, decidedly.

Q. Suppose an increment determined by this method of ratio of fluctuations for a whole year, and no consideration is given to ice effect, but is based entirely upon the conditions during the open season, would such an increment be higher or lower than an increment which took into consideration the ice effect?

A. If we proceeded from the increment of the Niagara River to that of the St. Clair River, the derived increment for that river would naturally be too large, if the effect of ice was neglected. The reason for that is that the increment of flow at the time when the river is partially obstructed with ice is less than when the river is open. And this is borne out by observations of the Lake Survey, which were made from 1899 to 1902.

Q. What bearing would that have upon a lowering caused by a diversion, say at Chicago through the Drainage Canal?

A. The mean increment for the year, considering or including the ice effects would be smaller than the increment during the open season; and assuming that the Chicago diversions were uniform throughout the 12 months, the effect would be greater than shown by the open season increment.

Q. Now to what lakes does that refer?

A. That refers particularly to Lakes Huron and Michigan. There is also some ice effect on the St. Lawrence River, which partially obstructs the flow from Lake Ontario, and in a similar manner decreases the mean annual increment somewhat below open season increment.

Q. What is your opinion as to the degree of precision that can be made in soundings and in determining the area of a cross section, in such sections as have been used in the measurement of these rivers that you have mentioned?

A. I believe the results are correct within 1/2 of 1 per cent.

Q. On what do you base that, Mr. Ray?

A. Upon the accuracy with which soundings can be taken, and also the length of the section.

Q. Are you familiar with the conditions on the Niagara River at the Bridge Section and at the Open Section as to the condition of flow?

A. Not except what I have seen from the shores and from the bridge.

Q. Is it any great degree of perturbation?

A. I didn't observe any.

Q. What is your opinion as to the consistency of the three rivers, taking into consideration the measured volume of flow of each of them?

A. You mean the mean volume of flow?

Q. You mean, yes?

A. I have failed to find any reason for believing that they are inconsistent. I have made some analysis of the supply (local supplies to the lakes), and applying the derived quantities to the discharges, they showed results which are in accordance with each other to a degree that was satisfactory, considering the data that we had in regard to the supply.

Adjourned to Wednesday February 4th, 9:30 A. M.

Wednesday February 4th, 9:30 A. M.

F. G. RAY resumed the stand for further direct examination by Mr. Hopkins and testified as follows:

Q. Mr. Ray, are you familiar with the method used by Mr. Williams, as it appears in his testimony for computing the increment for the St. Clair, the Niagara and the St. Lawrence Rivers?

A. I have looked over the methods that he has used. I have not checked any of the computations.

Q. Will you state generally what that method is?

A. As I understand the computations that he has made, he has selected certain observations, or certain periods during which observations were taken, and grouped these observations and determined the mean of each group, and the mean of the daily mean gage readings covering a certain period, which in some cases begins from 24 to 38 hours or such a matter previous to the first observation in this group, and ending about a day before the final observation in the group.

Q. Now take the reference to the St. Clair, what was his method?

A. On the St. Clair River, he has taken selected groups of observations and determined the mean discharges, or rather the weighted mean discharges of each of the various periods into which these selected observations are divided, and has referred these to the stages of Huron and St. Clair determined by mean daily gage readings; the Huron stage covering the days in which the observations were taken; the St. Clair mean determined from the daily mean stages commencing one day previous to the first observation in the group, and ending one day previous to the last observation in the group.

Q. What paper or document are you referring to?

A. I am referring to Williams' Exhibit 34, Table XXVIII.

Q. In what respect if any does it differ from the Lake Survey Method?

A. In referring the discharge observations to the gage heights, and in the reduction of formula by the Lake Survey, it has been customary to refer to the mean height of local gages, and by that I mean the gages in the immediate vicinity

of the discharge section, covering only the time of the discharge work. These gage heights are then transferred to Huron elevations and St. Clair elevations by means of water level transfers, or in other words comparison of gage heights, the gage relations determined over a long period of time.

Q. Just what do you mean specifically when you speak of the time or times of the observation?

A. The periods during which observations were actually being made.

Q. You mean the two or three hours?

A. Yes, the period covered by the observation.

Q. That is the time covered by a particular observation?

A. Covered by each individual observation.

Q. How long would that be on the St. Clair?

A. I don't know as I can give that very closely. The time varied considerably between the work on the Dry Dock Section and the Gorge Section. The Gorge Section was the shorter section, and measured in less time.

Q. Can you give that roughly?

A. Roughly I should say two or three hours.

Q. Now what was the method at Niagara used by Mr. Williams?

A. Referring to Table XLVa, of Williams' Exhibit 34, I find that he has followed a similar process in selecting observations covering certain periods; that he has taken the weighted mean of the discharges during each of these periods and has referred them to stages of Lake Erie as determined at Buffalo from daily mean gage readings covering a period including the day previous to the first observation in each group, and including the last day covered by the observations.

Q. Now as to the weighting of the observations there?

A. The weight given to the observations is determined apparently from the number of observations taken during the day, and is inversely as the number of these observations. In cases where observations are not taken during any one day in these periods, the observations of the previous and following days are given additional weight.

Q. Suppose that four observations each day were made, on three consecutive days, what weight would be given to the observations on the middle day?

A. I do not find such a case exactly, but I judge that a weight of .25 would be given to each observation in such case.

Q. That is the four observations would be treated as a single observation?

A. The four would be treated as a single observation, and would be given a weight of one.

Q. What effect would the Lake Survey give to those four observations, what weight?

A. Each observation would be given a weight of one. In other words they would all be weighted equally.

Q. Now referring to Table XLI, what is Mr. Williams' method in regard to the St. Lawrence?

A. I judge by an inspection of Table XLI that the discharge measurements on the St. Lawrence River have been grouped similarly to those on the St. Clair and Niagara Rivers and weighted in the same manner. There the weighted mean discharge determined from each group is referred to the stage at Ogdensburg, determined from daily mean water levels on that gage and covering a period including one day previous to the first observation in each group, and ending one day previous to the last observation in each group.

Q. How long does it take the influence of the level of the water at Ogdensburg to be felt at Three Point Section?

A. Something over two hours; my recollection is about two hours and a quarter.

Q. Somewhere between two and three hours?

A. Between two and three hours.

Q. How many hours did Mr. Williams take?

A. The center of gravity would be 24 hours to the observation.

Q. Of what value in your opinion is this method of Mr. Williams in deriving the true increment?

A. It is my opinion that this is not a correct method; that it introduces, or may introduce stages of water which have no influence whatever on the discharge, at the time that the observations are being taken.

Q. Have you made any study of the effect, or as to whether or not there has been any effect upon the level of lakes Michigan-Huron by government improvements in the St. Clair and Detroit Rivers?

A. In 1909, I prepared a report for a Board of Army Engineers analyzing the probable effects on water levels of the construction of the Livingstone Channel.

Q. Please identify the report.

A. The report was published in document number 676, 61st Congress 2nd Session, House of Representatives.

Q. What is your opinion now as to the effect if any of the work in those rivers on the level of Michigan-Huron?

A. In further answer to your previous question, I will say that in making this analysis I undertook to derive an equation representing the stage of Lake St. Clair in terms of Lake Huron and Erie, as a basis for determining the effect of the Livingstone Channel. The solution from which this equation was derived came out exceedingly satisfactory and indicated to me that Lake St. Clair had retained its normal position between Huron and Erie during the period covered by gage observations on Lake St. Clair.

While it practically held the same position, the indications are that the change if any did not exceed 1/10th of a foot during this time. I also made some further studies in regard to the relative elevations of Huron and Erie, independent of St. Clair. The stages of these two lakes can be grouped in various ways and comparisons between the various groupings indicate a relationship covering a considerable range; I believe something between 60 and 90 per cent. variation on Erie for 1 foot variation on Lake Huron.

This solution is not very satisfactory owing to the fact that it gives different values for different manners of grouping. Some of these groupings indicate decreased fall in the two connecting rivers amounting to .1 to .3 of a foot.

The previous analysis that I speak of would indicate that if there had been a change in regimen or a decreased fall in either river that it also occurred in the other.

A further examination of the fall from Huron to Erie was made by comparing the stages during the earlier periods of record with those during the most recent period, and—to obtain stages that were directly comparable,—I took a grouping of the five lowest stages on Lake Huron and corresponding stages on Lake Erie out of the first 15 years of lake level records. The mean stage on Lake Huron for this period was 580.95. The mean stage on Lake Erie for the same period was 572.33, showing a fall between Lake Huron and Erie of 8.62 feet.

During the last 15 years of record, up to 1908, the five highest annual mean stages on Lake Huron were selected, and the mean of these gave a stage for Huron of 580.95, identical with the mean of the five taken during the earlier period.

The mean stage for Lake Erie during the same years was 572.36, showing a fall between Huron and Erie of 8.59 or .03 of a foot less than determined by the group in the earlier

period. The only reason for selecting these years, as was done, was to get a stage that was comparable. The latter period was taken up to and including 1907 but excluding the years later than that during which construction work on the Livingstone Channel was in progress.

This analysis would indicate to me that there has not been any great disturbance in the regimen of these two rivers.

Q. A little more in detail, what do you mean by no great disturbance in the regimen, in tenths of a foot, or in inches.

A. This analysis indicates that there is no appreciable change in the fall from Huron to Erie; that if there is actually a change it is too small to be determined in this method of analysis.

Q. Would your method of analysis detect a change as large as half a foot?

A. This would indicate to me that the change if any had not exceeded one or two tenths of a foot.

Mr. Austrian: Can we not get an answer to your question? I would like an answer to the other questions, too.

Mr. Hopkins: All right, answer my question, and let this answer stand.

Q. (Question read as follows: "Would your method of analysis detect a change as large as a half a foot")?

A. Yes, it certainly would.

(Chart produced and marked Ray Exhibit 1, February 4, 1914.)

Mr. Hopkins: We offer this in evidence.

(Charts produced and marked Ray Exhibits 2 and 3, February 4, 1914.)

Mr. Hopkins: Q. Is it possible to determine the increment at Niagara in any other way than the way indicated by you yesterday?

A. It is possible to eliminate the Buffalo gage from the problem by referring the discharge observations to any other gage on the Niagara River, or a gage in close proximity to the discharge section, and then relating that gage to some other gage on Lake Erie, this relation being determined by comparisons of gage readings at the Niagara River gage and the Lake Erie gage, covering a period long enough to determine a definite relation between these two gages.

The relation of discharge measurements on the Niagara River, with respect to these other gages on that river will determine an increment of the critical section measured by any such gage. And then introducing a factor determined

by the relation of that gage to a lake gage, the increment can be transposed into the increment for Lake Erie.

Q. Is that a correct method of proceedure?

A. I would consider it correct, but the determination of increment would probably not be as good as the one determined by reference directly to the Buffalo gage, as it would require two steps instead of one.

Q. I show you Ray's Exhibits 1, 2 and 3 of this date, and ask you to tell what those exhibits are, what they show. Take first Exhibit 1; get them in order?

A. On Exhibit 1 are plotted monthly mean gage readings at Cleveland and at Suspension Bridge gage on the Niagara River. These monthly means are plotted with elevations on Suspension Bridge as ordinates and elevations at Cleveland as abscissa. A line is drawn through the center of gravity of these monthly means, and I will say that these monthly means cover 12 months, July, August, September and October 1906, June, July, August, September and October 1907, June, July, August, 1908.

They cover a range of about 3 feet on Suspension Bridge gage. A line is drawn through the center of gravity representing the mean of the 12 months, and this line represents the relationship between the two gages. Assuming that this plot is correct and that the reduction indicated hereon is also correct, the line shows a fluctuation on Suspension Bridge of 2.334 times the fluctuation on the Cleveland gage.

There is also plotted on this same sheet for the same months the monthly mean stages at the Whirlpool gage on the lower Niagara River against the similar monthly means at Cleveland, and the line through the center of gravity of these points as shown hereon represents the relationship between these two gages, and the factor representing the relation of fluctuations is 2.611.

Exhibit number 2, shows a plot of the 118 discharge measurements made in 1907 and 1908, at the Bridge Section and these are plotted with respect to the stage at Suspension Bridge. These observations are combined into groups of ten each, excepting the last, which contains only eight. The line through the center of gravity of these observations, and trending along the plottings of the various groups represents the discharge curve of the Niagara River with respect to the Suspension Bridge gage.

Assuming that the plot is correct and that the reductions are also correct, the increment is shown to be 9,445 cubic feet

per second for 1 foot change of stage on Suspension Bridge gage.

There is also shown on this exhibit a computation of the increment for Lake Erie, applying to the increment for the Suspension Bridge gage the ratio of fluctuations between the Suspension Bridge and Cleveland gages. This computation shows an increment for the Cleveland gage of 22,000 cubic feet per second.

Exhibit number 3, shows a similar treatment of the observations with respect to the Whirlpool gage. On this sheet there are only shown 108 discharge measurements grouped in groups of ten in order of stage, excepting that the last group contains only eight.

The line representing the discharge curve through these observations indicates an increment on the Whirlpool gage of 8,585 cubic feet per second. Applying to this the co-efficient representing the relationship between the Whirlpool gage and the Cleveland gage, namely 2.61, determines an increment for the outflow of Lake Erie with reference to the Cleveland gage of 22,400 cubic feet per second. The results obtained by these two analyses eliminate entirely the Buffalo gage.

Q. Mr. Ray, assuming that the observations on Exhibit 1, just mentioned were correctly plotted, in your opinion does the line on those exhibits substantially represent the law of fluctuation?

A. I believe it does so far as the law of fluctuations can be determined from that number of comparisons.

Q. Now referring to page 31, of "Preservation of Niagara Falls," Senate Document number 105, do the figures on those exhibits as to ratio of fluctuation substantially check those referred to in that report?

A. The ratio of change shown in the table you have referred to, comparing Suspension Bridge with Lake Erie, is 2.29, and in the comparison on the exhibits is 2.33. The ratio of fluctuation for Whirlpool, is stated in the report as 2.47, and the determination on Exhibit 1 is 2.61.

Q. If you were to use the ratio of fluctuations as indicated by that table in the report referred to, what effect would that have upon the increment derived for Lake Erie?

A. In both cases the increment would be determined to be less than indicated on the exhibits.

Q. By how much, approximately?

A. In the case of Suspension Bridge, the difference would

be about 2 per cent., and in the case of Whirlpool, between 5 and 6 per cent.

Q. Now referring to Exhibits 2 and 3, assuming that the observations on those two exhibits are correctly plotted, do the lines there substantially show the law of relationship between the gage and the discharge?

A. I consider that they do, very closely.

Q. What effect do these three exhibits and what they show, as you have testified to, have upon the increment, or your opinion of the increment as given yesterday of Niagara River?

A. I consider that they are a very close check and are corroborative of the increment determined from the Buffalo gage by the Lake Survey.

Mr. Hopkins: I offer those three exhibits in evidence.

Q. In your testimony yesterday you said that you thought the increment of the Niagara River was more properly represented by a curve than a straight line. Now does that check with Haskell's Exhibit 1?

A. The increment by the straight line shown on Haskell's Exhibit 1, is 21,900. The increment determined by the curve line formula for the stage representing the center of gravity of all observations on the Niagara River is 22,010; a difference of about 110 cubic feet per second, per foot.

Q. Mr. Ray, do you know what work is going on at the Welland Canal?

A. I am informed that the improvement of the Welland canal is in progress, or at least that a number of contracts have been let for deepening the canal, and for the construction of new locks. The canal when completed under the present plans is to have 25 foot depth through the prism, and a depth over the lock sills of 30 feet.

Q. The Welland Canal is a canal connecting Lake Erie and Lake Ontario, isn't it?

A. It is.

Q. Now, since your former testimony, what has been the tendency in regard to the size of boats on the Great Lakes?

A. The tendency has been to build larger, longer and deeper draft boats.

Q. A little more in detail, Mr. Ray?

A. I saw a statement in an official report not long ago, and I don't know the date of the report, but the statement is a recent one and shows that in 1904, there were no boats on the Great Lakes over 500 feet long. Now, there are 139

boats over 500 feet long, 12 of which are over 600 feet. The increase in draft of the recently built boats is also noticeable; that is the provision for greater draft.

Q. About how many tons do those large boats carry per inch of draft, say, after they are loaded to 19 feet?

A. Somewhere about 90 tons per inch of draft.

Q. Mr. Ray, for a diversion of 10,000 cubic feet at Chicago, what would be the effect in inches upon the level of Lakes Michigan and Huron, Erie and Ontario, and the harbors and channels of those lakes?

Mr. Austrain: That is, what will be the effect in his opinion?

Mr. Hopkins: Yes, in your opinion

Mr. Adcock: As based upon these observations and records?

Mr. Hopkins: No, leave it as it is: What in your opinion will be the lowering in inches?

A. As determined by the Lake Survey discharge formulas, the lowering of Lakes Huron and Michigan for a diversion of 10,000 cubic feet per second would be 5½ inches; on Lake Erie about the same, and on Lake Ontario the lowering would be between 5½ and 5¾ inches; and these lowerings that I have given are determined by using open river increments. The effect of ice gorges in the rivers is to reduce the increments, the mean increments for 12 month periods, and accordingly the effect of the diversion would be greater than indicated.

Q. Will that same effect occur in each of the harbors of those lakes?

A. The same effect would be felt throughout the lakes and harbors.

Q. How about the rivers, St. Clair, Detroit, Lake St. Clair?

A. The lowering in the St. Clair and Detroit Rivers would be approximately the same as the lowerings in Huron and Erie.

Q. How about Lake St. Clair?

A. The same would apply to Lake St. Clair.

Q. How about the entrance to the Welland Canal, and the entrance to the Erie Canal?

A. The effect would be the same in the entrances to these canals, as far down as the level of these canals were approximately the lake levels.

Q. It would be the same as what?

A. Same as the lowering on Lake Erie, about 5½ inches.

Q. And for Ontario, the entrance of the Welland Canal into Lake Ontario?

A. The effect on the entrance to the Welland Canal from Lake Ontario would be essentially the same as for Lake Ontario.

Q. Suppose instead of 10,000, the diversion at Chicago were 4,000 or 8,000 cubic feet, would the lowering be in the same proportion as for 10,000?

A. The lowering would be in direct proportion to the amount diverted.

Q. And as to 14,000?

A. The same would apply as to 14,000.

Q. Now with reference to navigation, is there any importance in the depth of the whole length, the whole lake, as distinguished from a particular channel?

A. The lowering of the whole lake would be the same as the lowering in the harbors and the channels.

Q. With reference to navigation, do boats confine themselves in all cases to a particular channel, or do they need more room at times?

A. The lowering would not be injurious to navigation on the open waters of the lakes, where the waters were deep. As the boats made use of shoaler waters, the effect of the lowering would be injurious to navigation,—providing the shoaler depths produced a limit to the draft of the boats.

Q. In times of storm and fog, the vessels do get off the channels, do they not?

A. They do.

Q. What knowledge do you have of the water power development at Niagara Falls?

A. I have a general knowledge of the power development situation, through having had to do with the supervision of the power companies at Niagara Falls and the measurement of their diversions.

Mr. Austrain: Q. As a government officer or individually?

A. Officially.

Mr. Hopkins: Q. Will you go ahead and tell us as to the measurements made in the diverting canals, and what horse power is developed per cubic foot of water and the values per horse power?

A. The Lake Survey has made measurements of flow in the diversion canal of the Niagara Falls Power Company and in the canal of the Hydraulic Power Company, in connection with the supervision of operations of these companies; the

purpose being to determine the relation between diversion and output in electrical horse power. The object of determining this relation was to expedite and make more convenient the process of supervision of the companies, placing limitations on their output which represented the diversions that were allowed them by law.

Q. How are the measurements made as to what they shall divert?

A. The measurements were made with the Haskell Current Meter in the diversion canals of these companies.

Q. Any check upon that measurement, with reference, first, to the Pitot Tube?

A. In measuring the flow through the diversion canal of the Niagara Falls Power Company, these measurements were made on two entirely independent sections in the canal, and the results obtained by these two series of measurements checked within about ½ of 1 per cent.

Mr. Austrian: Q. When were those measurements made?

A. 1907 I believe.

Mr. Hopkins: It was in 1909, wasn't it?

A. Additional measurements were made in 1909; the first measurements in 1907. The 1907 measurements were made to determine the amount of diversion then being made by the company; those in 1909 were made to determine the efficiency of the generating units and turbines in the two power houses, with an idea of constructing an efficiency curve representing the efficiency of development for different operating conditions.

The Niagara Falls Power Company at that time were operating the two power houses, numbers 1 and 2. The turbines in these two power houses were of a different type, and were developing at different efficiencies. The measurements determined the efficiency of development for each of the power houses independently.

In 1910, the Niagara Falls Power Company started rebuilding the generating units and installing new turbines in power house number 1, with an idea of increasing the efficiency of this station. The company made representation at that time to the government that it was increasing the efficiency of its plant, and desired a new determination of the efficiency of the reconstructed units. The Lake Survey at that time co-operated with the Niagara Falls Power Company in measuring the efficiency of one of the reconstructed units, and these measurements were made by the use of a

Pitot Tube in the penstock. At the same time, similar measurements were made in one of the old penstocks to determine the relation (as measured with the Pitot Tube) between the reconstructed and the old units. The results obtained with the Pitot Tube in the penstock of one of these old units in power house number 1, were directly comparable with the determinations made with the current meter in the canal of the power company.

The efficiency curve as determined with the Pitot Tube checked with that determined by the current meter in the canal within about 1½ per cent. The current meter indicated in this check the flow of water 1½ per cent. larger than that determined by the Pitot Tube.

Q. Will you describe a little further this Pitot Tube, and the accuracy of tests made with that, in comparison with the Haskell Meter?

A. The Pitot Tube is one built especially for the work by the Niagara Falls Power Company, and it was constructed so as to offer the least possible resistance to the flow of water in the penstock, and so that it could be operated without any bars or obstructions in the penstock. The Pitot Tube was rated in still water previous to and following the measurements in the penstock. The results obtained with the Pitot Tube were very accordant and indicated that the results were to be depended on as being of a high degree of precision.

Q. Does the Power Company accept the measurements of the Lake Survey?

Mr. Austrian: Object to that as incompetent.

A. They have accepted the measurements without protest and are operating, have been operating until the expiration of the Burton Law, under the limitations that were prescribed by the Lake Survey.

Mr. Austrian: I move the answer be stricken out as incompetent, irrelevant and immaterial; not responsive to the question.

Q. Now as to the efficiency of the turbines,—perhaps to put it better: Have you determined the horse power per cubic feet of water per second?

A. The present development of the Niagara Falls Power Company is about 10 electrical horse power per cubic foot of water diversion.

Q. What would you say as to the turbine efficiency?

A. The efficiency in power house number 1, was determined to range from about 34 per cent. at 50 per cent. gate opening up to 57 or 58 per cent. at full gate opening. In

power house number 2, the efficiencies over this range were from 53 to 72 per cent. and these efficiencies represent the determination of the relation between diversion in the canal and the output on the switchboard. Included in the amount of water used in this determination were also the wastes and the amount used for excitation.

Q. Go ahead and explain further your answer?

A. This efficiency is determined in power house number 1, for a head of 136 feet; in power house number 2, 140 feet, and this is the head between the canal and the wheel pit. In the case of power house number 1, the units in this station had no draft tubes, and the head of 136 feet represent the fall from the canal to the outlet of the turbine.

Q. Are those high or low efficiencies?

A. They are particularly low in power house number 1, and I believe somewhat below the efficiency of development now obtained by recently built turbines. These efficiencies must be understood to include all wastes and the use of water for various purposes around the plant.

Q. What is the market value per horse power of this electrical power for commercial uses at Niagara?

Mr. Austrian: We object to that; has no relation to this case.

Mr. Adcock: Furthermore the witness has not been shown to be qualified to answer that question.

Mr. Hopkins: Are you acquainted with the market value of power in and around Niagara Falls?

A. I have very little definite information—

Mr. Adcock: Objected to on the further ground that counsel cannot prove a witness' fitness to answer as an expert on a question of that sort, by asking whether he is qualified.

Mr. Hopkins: Go ahead, tell what you know about it.

A. I am not very well qualified to discuss the market value of electrical power at Niagara Falls. The situation is rather complex there. The power is handled in various ways by distributing companies, and to commercial factories. I am informed that the commercial power at Niagara Falls is about $18 a horse power per year.

Mr. Adcock: I move the answer be stricken out, as regards the statement of the horse power at Niagara Falls.

Mr. Hopkins: Q. Mr. Ray, are you acquainted with the Drainage Canal at Chicago?

A. Not from personal observation except that I have seen the canal. I have crossed the canal at times. The Lake Sur-

vey recently made measurements in the canal. Mr. Moore had charge of the measurements and these measurements were made under instructions drafted by myself, and I am familiar with the work done and with the results obtained.

Q. Mr. Ray, suppose a canal from Lake Michigan to Lockport, Illinois, or rather a canal from Robey street, Chicago to Lockport, Illinois, and from Lake Michigan to Robey street, the Chicago River about six miles, of sufficient size to carry 8,000 cubic feet of water at a mean velocity of a mile and a quarter per hour; from Robey street for eight miles the canal is 110 feet wide on the bottom, and 210 feet wide on the top. The next five miles it is 202 feet at the bottom and 300 feet at the top. The next 15 miles it is 160 feet at the bottom and 162 feet at the top, making a total of 34 miles to the controlling works; then it is 2 miles from there to the power house where there are other controlling works, making a total of 36 miles from Lake Michigan. Assuming that the depth in the Chicago River is 26 feet and the depth in the canal, which is the lower 30 miles of this channel, is 24 feet substantially.

Supposing further that there is a flow through that channel from Lake Michigan to Lockport of 4167 cubic feet per second, and suppose that at the controlling works at Lockport the canal is opened, or gates opened to a capacity of 14,000 cubic feet per second, how long would it take the effect of that opening to appear throughout the entire length of the channel, even to Lake Michigan, so that 10,000 cubic feet would flow towards Lockport and not into Lake Michigan?

A. In my opinion the time required to set up the flow through the canal to Lake Michigan would be between 2 and 3 hours, not exceeding 3 hours.

Q. That is a flow of 10,000 cubic feet in the direction of Lockport?

A. That is correct.

Mr. Hopkins: That is all Mr. Ray.

Cross-examination reserved.

Friday, February 20, 1914, 10:00 A. M.

F. G. RAY, resumed the stand and testified further as follows:

Cross-Examination by Mr. Adcock.

Q. You are Principal Assistant Engineer, are you not, at this office? (Lake Survey.)

A. I am.

Q. And have you held that position since 1909?

A. Since the fall of 1909.

Q. What are the duties of your position?

A. I have had general supervision of the field and office work of the Lake Survey, under the direction of the Army Officer in charge, and have had charge of the care and repair of floating plant; and in fact all operations of this office.

Q. What do you have to do with the preparation of the annual reports to the Chief of Engineers?

A. I have had considerable to do with the preparation of the reports of this office.

Q. Do you approve all reports that are made by this office to the Chief of Engineers?

A. Subject to the approval of the Officer in Charge.

Q. But all reports that are made to the Chief of Engineers are approved by you, are they not?

A. I believe they have been since I have been here, but not necessarily so.

Q. What if anything did you have to do with that part of the report for 1910, appearing on pages 1043 to 1050 of Appendix GGG?

A. I made a draft of that portion of the report, but I am not positive that it stood as it was originally drafted.

Q. The substance was the same?

A. The substance was practically the same. This is the report of the Chief of Engineers. The draft was prepared in this office, and revised in the office of the Chief of Engineers.

Q. What did you have to do with that part of the report for 1911, appearing on pages 3011 to 3018, being section headed "Surveys" in Appendix FFF of the Report of Chief of Engineers for 1911?

A. I prepared that report, and I believe it was published as prepared by me.

Q. What did you have to do with the section headed "Surveys and Investigation of Lake Levels" appearing on pages 3535 to 3548 of Appendix FFF, of the Report of the Chief of Engineers, for 1912?

A. I also wrote the draft of that report.

Q. On page 3547, of Appendix FFF, report of the Chief of Engineers for 1912, there are given certain formulae for the discharge of St. Clair, Niagara and St. Lawrence Rivers. Are those formulae correct ones to apply to these rivers, in your opinion?

A. I believe those are the best formulae that we had at that time, derived from all the hydraulic data.

Q. That is based upon the records of measurements of those rivers and the gages, etc.?

A. These formulae are the results of new reductions of all of the hydraulic data then on hand, and are the best representations of the data at that time that we could prepare.

Q. And simply referred to the data that you had on hand then, that is all

A. Yes, necessarily so.

Q. Are they the same as those referred to by various witnesses for the complainant in this case, upon which exhibits Complainant's Exhibits 1, 2, 3 and 4 are based?

Mr. Hopkins: I think you ought to name more definitely what witnesses you are talking about.

A. The witnesses, Haskell, Noble, Ernst, Curtis MacDonald, Townsend, Wheeler?

The Witness: Considering when these were made, I can tell you definitely they were not.

Q. (Question read as follows: "Are they the same as those referred to by various witnesses for the complainant in this case, upon which exhibits Complainant's Exhibits 1, 2, 3 and 4 are based"?) Do you know of your own knowledge?

A. The formulae published in the 1912 report, were prepared or derived after the testimony to which you refer was given; with the exception that the discharge formula for the Niagara River was not changed from the curved line formula that had been used previous to the time of the witnesses' testimony.

Q. You have Complainant's Exhibits 1, 2, 3 and 4, before you there, haven't you?

A. I have copies.

Mr. Hopkins: You have what was handed you and alleged to be copies?

A. Alleged copies.

Mr. Adcock: Do you know whether the formulae referred to on page 3547, Appendix FFF, report of the Chief of Engineers, 1912, are the same formulae as those upon which the exhibits, Complainant's Exhibits, 1, 2, 3 and 4, are based?

A. They are not.

Q. Do these equations give the same results?

A. They do not give precisely the same results.

Q. Are these equations the same as those given in the report of the International Waterways Commission on the Regulation of Lake Erie under date of 1910?

A. They are not.

Mr. Hopkins: When you say "these equations," which ones do you refer to, the exhibits 1, 2, 3 and 4 of FFF, the equations contained in them?

Mr. Adcock: FFF. (Q) Do they give the same results?

A. They do not.

Q. In the report of the Chief of Engineers for 1911, Appendix FFF, page 3013, there is the following statement: "A few relations of gage heights have been derived, and the observed discharges have been compared graphically with former values, both indicating an increase of about 3 per cent. in the volume of flow through the St. Clair River at mean stage since the determinations of 1899 to 1901. This change is attributed to the effect of recent dredging in the upper river." At the time that statement was published, was it approved by you?

A. It was.

Q. It was?

A. It was.

Q. By whom was the dredging done, and where was the dredging done that is referred to in that report?

A. I am not positive by whom the dredging was done. There was some dredging--

Q. I do not mean the contractor. Was it done by the United States Government or by John Smith?

A. It was not by the United States Government.

Q. It was not?

A. It was not.

Q. Do you remember by whom it was done?

A. The dredging at that time was being done by private companies, dredging gravel from the bottom of the river.

Q. Where was that dredging?

A. That was mostly between the Gorge and Dry Dock Sections and near the head of St. Clair River.

Q. Was it done under authority of the United States Government?

A. I am not sure. There was some controversy in regard to the dredging there, and I believe it was finally stopped by the United States Government.

Q. An increase of three per cent. in the discharge of the St. Clair River would lower the level of Lake Huron by how much in your best judgment?

A. About a quarter of a foot.

Q. Has anything been done to replace the dredging or the material dredged, or to compensate for it?

A. There has been no artificial compensation for that dredging.

Q. How much material was taken out, do you know?

A. I do not.

Q. Approximately, can you state?

A. I don't even know approximately. I never investigated. There was considerable gravel taken out of the bed of the river, and some quite deep holes dug.

Q. More or less than a million cubic yards?

A. I have absolutely no idea.

Q. For what period of time has the dredging been carried on?

A. There has been more or less gravel removed from the upper St. Clair River, for a great many years.

Q. When you stated that the effect upon the levels of Lake Huron would be about a quarter of a foot, you based that entirely upon the records of discharge measurements and the gage readings which have been referred to in this case, on the St. Clair River?

A. I believe, if I understand what you mean, the three per cent. increase in flow would be equivalent to between five and six thousand cubic feet per second, which would have an effect of somewheres in the neighborhood of a quarter of a foot.

Mr. Adcock: Will you read that question?

(Question read as follows: "When you stated that the effect upon the levels of Lake Huron would be about a quarter of a foot, you based that entirely upon the records of discharge measurements and the gage readings, which have been referred to in this case, on the St. Clair River?")

Mr. Adcock: Made by the Lake Survey.

Mr. Hopkins: Objected to as unintelligible.

A. A change in flow of three per cent. would be equivalent to a change in stage of about a quarter of a foot.

Q. And that is based upon the increment which you have derived from the records of discharge measurements and gage readings?

A. It is.

Q. Made by the Lake Survey?

A. It is.

Q. Would the filling in on the deep sections of the St. Clair River to leave a depth of say 35 feet be an obstruction to navigation?

A. It would be no obstruction to the present navigation.

Q. You don't wish to speculate on the—

A. I don't wish to speculate just now on what effect it would have on the current velocities.

Q. In the report of the Chief of Engineers for 1912, Appendix FFF, page 3545, at the bottom of the page is given a formula for the discharge of the St. Clair River, in which there is a term *Y*. What does that *Y* represent?

A. That formula is purely an empirical formula, in which *Y* represents in a way the mean bed of the river.

Q. In what way does it represent it?

A. The elevation.

Q. At the bottom of the page referred to, the Chief of Engineer's Report, are given the values of *Y* for certain years. What was the elevation of the river bed in 1899?

A. That was not the elevation of the river bed. It is an empirical formula in which that term *Y* may be taken as representing the regimen of the river, elevation of the river bed.

Q. What is the value of *Y*?

A. The value given is 567.44.

Q. And in 1900?

A. 567.58.

Q. According to that, the river had filled up about two inches, hadn't it?

A. Those are the values that fit in this formula more closely to the observations.

Q. Doesn't the formula indicate such a filling?

A. That variation in the value of *Y* for the different years includes changes in regimen of the river. It may also include slight changes in gages; and may also include some slight difference in the discharge measurements taken by different field parties and under different conditions, and with the different instruments.

Q. It was necessary to adopt this elevation, in order to make the formula fit the observations, was it not?

A. The elevations were derived by mathematical solution, and are the values which most closely agree with the observations.

Q. Was the method of least squares used in the derivation?

A. It was.

Q. What was the elevation in 1901?

A. 567.33.

Q. According to that, the river had scoured out approximately 3 inches?

A. Possibly.

Q. What was the elevation in 1902?

A. 567.64.

Q. And it had filled up nearly four inches?

A. It had.

Q. If the bottom of the river had raised an average of .31 of a foot, how much was the cross section decreased at mean stage?

A. I don't know as I understand your question.

Q. Would it be about 700 feet approximately?

A. I don't believe that it is possible to answer that question. The value there is derived for certain formulae, and may represent the average bottom of the river. The effect on the cross section would depend upon the width, and the river is of variable width.

Q. Do you know the average width?

A. I don't know offhand the average width of the St. Clair River?

Q. Approximately?

A. I would have to consult a chart.

Q. Isn't it approximately 5,000 feet?

A. (No response.)

Q. Assuming that the average width is about 2,000 feet, how much was the cross section decreased then at mean stage, if the bottom of the river were raised an average of .31 feet.

Mr. Hopkins: Q. Do you assume further that the width remained at the same place?

A. If the bottom was raised uniformly .31 feet, it would decrease the cross section at least 620 square feet.

Mr. Adcock: Q. Do you consider the average width to be about 2,000 feet?

A. I presume it is somewhere near that.

Q. How much was the so called hydraulic radius reduced by this change of the bottom?

A. The hydraulic radius would be decreased about the same.

Q. What would be the effect upon the discharge of reducing the hydraulic radius by the amount mentioned, the so-called slope remaining the same?

A. The discharge would change proportionately to the square root of the hydraulic radius times the area.

Q. Then it would be decreased?

A. It would be decreased.

Q. By that much?

A. Yes, by an amount in proportion to the square root of the hydraulic radius times the area.

Q. Would a reduction of the cross sectional area reduce the discharge, the slope remaining the same?

A. It would.

Q. Would the raising of the bottom of the St. Clair River in the amount mentioned raise or lower the level of Lakes Michigan and Huron for any given discharge?

A. It would, if it remained in such new position long enough for the backwater effect to be felt.

Q. It remained long enough to affect the discharge measurements?

A. These values were derived from the discharge measurements.

Q. Then the discharge measurements must have been affected by this change, must they not?

A. If the change is due to change in regimen, it would be.

Q. How much would this filling of the river of .31 feet raise the level of Lakes Michigan and Huron at mean discharge?

Mr. Hopkins: Assuming the width remained the same?

Mr. Adcock: Making the assumptions which have been made heretofore in connection with this proposition.

A. In answering your question, I wish to explain that I do not accept those values as being entirely due to changes in the bed of the river. In making a new reduction of the discharge measurements of the St. Clair River, we found that there seemed to be a difference between various years at the same stage. Whether or not that was entirely due to change in regimen, we do not pretend to know, but the new reduction was made separating the various years, for the purpose of deriving a better value for the increment; and it was done for that purpose only.

The change between the discharge values of the 1901 and the 1902 groups, as determined by this formula, was about 6,000 cubic feet per second, which is equivalent to a change in stage on Lake Huron of about a quarter of a foot.

Q. Then if no such change occurred in the river's bottom, your formula is incorrect, is it not?

A. No, I would not say that.

Q. Then the enumeration of the constants of the formula is incorrect?

A. The constants are derived by grouping each year separately; and the use of these constants in a formula makes the formula fit most closely to each group separately.

Q. And in the formula you give *Y* a certain value, do you not?

A. I do.

Q. And you say in the report:

"In applying this equation as first solved to the observed quantities, it is found that residuals were grouped by size or signs for the various years. Assuming that this variation of discharge for the different years of observation is due to change of regimen, the second solution was made in which the constants *K* and *A* were determined from all the observations, and *Y* which represents the elevation of the mean river bed, was determined for each separate year." Do you not so state?

A. That is correct.

Q. And in that you stated that *Y* represents the elevation of the mean river bed?

A. I do so state.

Q. When was it discovered that this change had taken place?

A. The new reductions of discharge that were made following the 1910 observations showed that there was some constant difference between various years.

Q. Was that about 1911 or 1912?

A. That was in 1910 and 1911.

Q. 1910 and 1911?

A. I would like to correct that. I think we finally derived the later values in 1911 and 1912.

Q. In establishing the fact of these changes of elevation of the bottom of the St. Clair River in 1899, 1900, 1901 and 1902, were any physical data made use of, obtained subsequently to January 1st, 1909?

A. The derivation of this formula included all observations of discharge from 1899 to 1910 inclusive.

Q. To what extent was the value of *Y* affected by any physical data secured after January 1st, 1909; that is the value of *Y* for the years 1899, 1900, 1901, 1902? You say the reductions were made in 1911 and 1912. Now I would like to find out what data, physical data was made use of that was obtained subsequently to January 1st, 1909, in making these reductions for the four years in question.

A. We used the discharge measurements made in 1909 and 1910.

Q. To what extent did these discharge measurements made in 1909 and 1910, which you speak of, affect the value of *Y* for the years mentioned, 1899, 1900, 1901 and 1902?

A. They would not affect the value of *Y* unless the increment was also affected. The value of *Y* is derived for these different years, and its manner of solution assumes that the line of increment is parallel in the groups of the different years. The observations in 1909 and 1910, added greater weight to the derived value of the increment.

Q. To what extent did they affect the value of *Y* in the percentages for those earlier years; was it an appreciable percentage?

A. That manner of solution was never applied to those previous years separately.

Q. If it had been, how great a difference would you have obtained?

A. It would take a week to figure that out, if you want an answer.

Q. You say it would take some time to figure it out. I will see if I can get at it in another way. What relation would this change have to the increment?

A. The manner of solution assumed that the increment was constant for each year, and the values of *Y* are derived on that assumption. If that assumption was not made, there would be a different increment derived for each year.

Q. In the event the discharge capacity of the St. Clair River had changed, wouldn't the increment change?

A. I doubt if the change in increment would be appreciable. The change would be less than the errors of observation, errors of determination.

Q. Wouldn't the increment change in the same proportion as the discharge capacity was changed?

A. Not necessarily.

Q. Would it change more or less?

A. I should say that it would change less than the change in capacity of the river.

Q. Are you positive about that, when referred to the St. Clair River?

A. I think so.

Q. In other words, if the capacity of the St. Clair River were, say 200,000 feet, discharging capacity; and that discharging capacity were afterwards reduced to 175,000 cubic feet per second, what would be if any the change in the increment?

A. Would that change in capacity be in depth or breadth or slope?

Q. Anyway, discharging capacity. Any way except widening of the channel at the water surface.

A. I would say that the increment would increase with an increased capacity, and the increase in increment would be slightly greater in proportion.

Q. I assume a decrease of the discharging capacity, Mr. Ray, in my question; assuming a fixed lake level.

A. (No response.)

Recess to 2:00 P. M.

After recess, 2:00 P. M.

F. G. RAY resumed the stand and testified further on cross-examination as follows:

(The testimony before recess was read to the witness, beginning with the question: "In other words if the capacity of the St. Clair were say 200,000 feet etc.")

A. I believe that generally speaking the increment would be less for the decreased discharge of the river. I am not sure that that would apply to the St. Clair River, unless all the conditions were known definitely.

Mr. Adcock: Q. Assuming that the discharging capacity was increased, would the increment increase?

A. I believe it would, slightly.

Q. Would it increase in as great a proportion as the discharging capacity was increased?

A. Approximately so.

Q. How near? When you say approximately, do you mean the same or—

A. To give a definite answer to that question, it would be necessary to know exactly how the capacity of that river was increased. It might be increased by enlarging the size of the channel at any point, or any short stretch along the entire length of the river.

Q. Suppose it were increased by lowering the average elevation of its bed?

A. I would expect to find that the increment increased nearly in proportion with the increased capacity.

Q. Do you think it would increase at a greater rate than the increase of the capacity?

A. I would not care to give a definite answer to that until I had time to work it out. That is a hydraulic problem which I have not worked with lately.

Q. You never have investigated that question in connection with your studies of the hydraulics of the Great Lakes?

A. Not in exactly that way.

Q. In what way have you studied that question, Mr. Ray?

A. (No response.)

Q. (Question read as follows: "Do you think it would increase at a greater rate than the increase of the capacity"). That is the increment. You say you never have studied it in that way. Now I ask you in what way have you studied the question as to the increase of the increment, proportional as the increase of the discharging capacity?

A. I have made some studies of the varying increments for different stages of the St. Clair River, as determined by the formula in the 1912 report.

Q. That is the formula which we referred to, in which *Y* was given certain values?

A. That is the same.

Q. Assume that *Y* were given a value of 5 feet less than is given in any one of the formulae, what effect would that have upon the discharge, the other conditions remaining the same?

A. It would materially increase the discharge for the same stages of the lakes.

Q. And the increment?

A. I am quite certain that the increment would be increased also.

Q. In a greater or less proportion than the discharge?

A. If the value of *Y* in the discharge formula for the St.

Clair River was decreased, the volume of discharge as derived by this formula would be increased and the increment would also be increased, in a less proportion.

Q. Then if the increment of a certain river were increased, that would indicate that the discharging capacity of that river had increased in a greater proportion?

Mr. Hopkins: Understanding all the time this is based upon the assumptions of the whole line of questions.

Mr. Adcock: We limit it to being increased by no change of width in the stream. That is all that is necessary.

The Witness: Generally speaking, an increase in the increment would accompany an increase of discharge.

Q. That is you mean by a greater percentage; that is the discharge would be increased by a greater percentage?

A. I would not care to say that. It would depend on the conditions by which that increase of flow was effected.

Q. Under what conditions then would it not be true? Are you ready to answer that question?

A. Only so far as I answered it before that a change in discharge or in capacity of the river, without changing the width would be accompanied also by a change in increment. If I understand your question correctly, I would say that the increment does not increase in proportion as fast as the volume of discharge.

Q. Is there any relation between the annual fluctuation of a lake and the increment of the outlet?

A. Do you mean whether there are any relations, definite relations between the annual fluctuations and the open river increment?

Q. And the increment of the outlet?

A. I think there would be.

Q. What is that relation?

A. A body of water which was dependent wholly for its supply upon another body of water would show a fluctuation in direct relation to the fluctuation on the supply basin, providing the channel between was unobstructed.

Q. And would you assume also that the increment—

Mr. Hopkins: That is the annual fluctuation you speak of now?

Mr. Adcock: Yes, I am speaking of annual fluctuation.

Q. Suppose that the increment of the St. Marys River, which is the outlet to Lake Superior, were 15,000 cubic feet per second, and that the increment of that river were decreased to 10,000 cubic feet per second, what effect would

that decrease have upon the annual fluctuations of Lake Superior? When I say "annual fluctuations," I mean the variations of annual stage.

A. If the outflow from Lake Superior were unobstructed by ice, the fluctuations would increase with the decreased increment.

Q. Suppose that it were obstructed by ice?

A. The change in annual fluctuations would then become indeterminate.

Q. Will you explain why?

A. The normal increments as expressed would not apply to the flow of water through the St. Marys River throughout the year in that case, and it would be practically impossible to determine the increment or at least we haven't that data during the time when the river is partly obstructed.

Q. But I am assuming in the question, Mr. Ray, that the increment is determined at 15,000 and there is a decrease to 10,000?

A. Is that the annual increment or the open river increment?

Q. That is the annual increment.

Mr. Hopkins: That assumes no ice.

Mr. Adcock: It assumes that that is the increment.

A. If the increment is assumed to apply to the annual flow, the fluctuations would change inversely as the change in increment.

Q. What change occurred in the elevation of the mean river bed of the St. Clair River from 1900 to 1901, as shown by the value of *Y* on page 3545 Appendix FFF, Report of the Chief of Engineers for 1912?

A. If *Y* is assumed to represent the mean river bed, the change shown is a lowering of .25 of a foot.

Q. That would be three inches, approximately three inches?

A. That would be three inches.

Q. This lowering produced a change in the formula for accurately computing the discharge of the St. Clair, did it not?

A. Those two values are values derived by a solution to fit the equation most closely to the center of gravity of the observations during the two years.

Q. And that solution was made by the method of least squares?

A. It was.

Q. And it was necessary to take account of it to get a

formula which would accurately fit the discharge measurements of 1901, was it not?

A. A single discharge formula for the observations of the St. Clair River did fit more closely to all of the observations; but as explained in the report, the residuals determined from a single equation were grouped by size or signs for various years, and it was believed to be better, to give a better determination of the increment by separating the yearly groups.

Q. You separated them and in your opinion gave a better determination?

A. A better determination of the increment.

Q. Were these changes in the river bed near the head of the river, do you know?

A. I don't think so; and I don't think that these values, different values of *Y*, are wholly due to change in regimen.

Q. Don't you consider that the waves drifted gravel and so forth into the head of the river, which was ultimately washed out at some other time?

A. I believe there has been some scouring and refilling of the bed of the river at various times.

Q. Near the head of the river?

A. At any place along the river, various places.

Q. So that it would change the mean river bed?

A. It would change the critical section of the river.

Q. Where is the critical section of the St. Clair?

A. The critical section is the entire length of the river. An obstruction in the river at any point between Lake Huron and St. Clair would change the flow through the river for fixed stages.

Q. Its discharging capacity?

A. It would change the discharging capacity.

Q. Have there been any recent surveys of the Niagara River, in the vicinity of Buffalo and the International Bridge?

A. There have.

Q. What was the occasion?

A. There was a new survey of the upper Niagara River from just above the Falls to Lake Erie made for charting purposes.

Q. What do those surveys indicate regarding the elevations of the bottom of the river as to whether or not there had been any changes discovered from the conditions existing at the time of the former survey?

A. The data of the upper Niagara River surveys have not

yet been plotted, and I am not able to answer that question.

Q. You spoke of ice in the St. Clair River in your direct testimony. Just what observations have you made personally with reference to that?

A. I have not made any.

Q. In the Lake Survey, have you any Engineer making observations with reference to the ice conditions in the St. Clair, who reports in writing to you?

A. Not to me.

Q. Who does he report to?

A. I don't recall that anyone has made observations on ice effects since 1909; that is anyone connected with this office.

Q. Is anyone connected with the Lake Survey making investigations, or anyone who has made investigations with reference to the ice in the Niagara River, who reports in writing to this office?

A. Not since 1909.

Q. For how many years prior to 1909 did the condition exist?

A. What condition?

Q. The making of reports with reference to ice conditions in the Niagara River?

A. I know of no reports concerning ice conditions, since the measurements that were made by Mr. Shenehon.

Q. And that was in the year 1899, 1900?

A. Yes.

Q. For how many years prior to 1899, did Mr. Shenehon make report with reference to the ice conditions in the Niagara River?

A. I don't recall that he made any report previous to that.

Q. And the same conditions were true with reference to the St. Clair River, were they not?

A. The observations during ice conditions on the St. Clair River were made by Mr. Sabin.

Q. At what time?

A. 1899, to 1901.

Q. For what length of time did Mr. Sabin observe the conditions of ice on the St. Clair River?

A. He made a determination of the ice effects for the winters of 1899-1900; 1900-01; 1901-02.

Q. In what cases did he actually measure the flow?

A. Mr. Sabin made actual measurements between January 2 and April 26, 1901.

Q. Did he make any actual current meter measurements of ice effects at any other time?

A. I believe not.

Q. Did anyone else connected with the Lake Survey?

Mr. Hopkins: You mean current meter measurements.

A. On the St. Clair?

Q. On the St. Clair?

A. I don't recall any.

Q. Wasn't the year 1901 a year of abnormal ice conditions?

A. It was.

Q. You gave in your direct testimony values of the increment of the St. Clair, Niagara and St. Lawrence Rivers, and you also stated that in your opinion a diversion of 10,000 cubic feet of water at Chicago would have a certain effect upon the levels of Lakes Michigan-Huron, St. Clair, Erie and Ontario. Were those conclusions as to the increment and the effect of diversion based entirely upon the reduction of the records of observations, records of discharge measurements and records of gage readings made by the Lake Survey, and referred to in this case?

A. They were.

Q. You stated that you visited frequently the field work of the hydraulic parties, since you have been Principal Assistant Engineer. Will you state just how frequently or how many times you were in the field during the measurements?

A. To the best of my recollection, I visited the hydraulic party when it was at work on the St. Clair River twice; while on the St. Lawrence River once; and once I visited the party engaged in measuring the discharge in the diversion canal at Niagara Falls.

Q. You say you followed the work closely? I presume you mean by that the work also of reducing the observations, don't you?

A. I do.

Q. What did you have to do with that work of reduction?

A. I supervised generally the reduction of the work and advised in regard to methods used, and also in regard to the form of the formulae to be derived, and consulted frequently with the men who were making the actual computations.

Q. You spoke of the value of water power at Niagara, a

certain value per horse power per year. Have you ever bought or sold any power?

A. I have not.

Q. You never bought or sold any electrical energy at Niagara Falls?

A. I have not.

Q. Did you ever try to buy or sell any?

A. I never did.

Q. You stated in your direct testimony that it would take about three hours to produce a uniform flow through the drainage channel from the power house to Lake Michigan (which includes the Chicago River) from a flow of 4167 cubic feet per second. What was that based upon?

A. That opinion was based on the time of travel of the wave set up by increased flow as observed by Mr. Moore, and the fact that the increased velocities traveled with that wave, or nearly so.

Q. Do you think that law would apply to the rivers as well as to the drainage channel?

A. I believe that the change in velocities would travel practically together with the change of stage.

Q. In rivers, the same as in the drainage channel?

A. In rivers, the same as in the drainage channel.

Q. Did you consider that the section at Lemont, which was selected by Mr. Moore, to measure the discharge of the drainage channel, was a good section?

A. It was not an ideal section, on account of an apparent obstruction somewhere above the section. That was not detected until after the measurements were under way.

Q. Do you consider that it would be more difficult to measure the flow of the drainage channel than that of the Niagara River?

A. The actual amount of labor involved would be less on the smaller stream. The percentage of accuracy I believe would be somewhat less than on the river.

Q. On the drainage channel than on the river?

A. Yes.

Q. Then you, in your opinion, could not measure the flow of the drainage channel as accurately as you could measure the Niagara River?

A. The actual flow could be measured much more closely in the smaller channel. In percentages, I believe it would be very difficult to attain the same percentage of accuracy as that attained in the large rivers.

Q. Will you give your reasons?

A. The sources of error are greater in percentage in the smaller stream. The indeterminate effects of the sides and bottom are greater in proportion. The percentage effects of stage perhaps are larger.

Q. Assuming that this section were in the rock cut, with smooth sides and smooth bottom; and also assume that for a long stretch both above and below the section the channel was straight and of regular cross section?

A. Do you also assume in that the flow is uniform, or nearly so?

Q. That would be the absolute discharge?

A. I believe it would be possible to obtain the absolute discharge with as great accuracy in the canal as in the rivers, but I do not believe this could be done with the large type current meter.

Q. You mean the B type, the B. Haskell Meter?

A. Yes.

Q. What would you use?

A. I would use a smaller type current meter and observe the curve of velocities closer to the sides and bottom with some other device, such as the Pitot Tube.

Q. Do you consider that you could measure more accurately the flow of a river half a mile wide with an average depth of 50 feet than a river a mile wide and 100 feet deep, average depth; other conditions being equal, same velocity?

A. With those dimensions, I don't believe there would be very much difference in the percentage of accuracy; while the larger river would be more difficult to measure, with respect to the amount of labor involved.

Q. But you believe that you could measure the flow of that river with the same percentage of accuracy that you could measure the other river?

A. The amount of difference would not be material, in my estimation.

Q. Then the larger the river the more accurately you could measure it, is that right? That is the percentage of error would be less?

A. That is not in conformity with my answer. I stated that there would not be an appreciable difference in the percentage of accuracy.

Q. Now you assumed in connection with your answer as to the length of time it would take to change the flow from 4167 cubic feet per second to 10,000 cubic feet per second

through the channel uniformly, that the change of discharge followed the change of stage immediately, did you not, or coincided with it?

A. A change in stage and change in velocity would not be proportional for different changes in the amount of flow. The increase of discharge following the change in stage, I believe might be greater or less than the final established uniform flow.

Q. Then am I correct in understanding that in your opinion the change in discharge does not coincide with the crest?

A. From what analysis I have made of that, I would say that they are not exactly simultaneous.

Q. How much variation?

A. The variation would be very small.

Q. In the Drainage Canal, a matter of how many minutes would it be, assuming that it takes three hours for the crest to travel from the power house to Lake Michigan?

Mr. Hopkins: You will fit the testimony better if you assume the three hours is for the full effect to be felt; if you want to fit the testimony.

A. The observations on the Chicago Drainage Canal do not show any appreciable interval of time between the change in stage and change in discharge.

Q. Do you think that is the general rule?

A. I do.

Q. Was the discharge of the Chicago Drainage Canal measured at two different points, two different sections?

A. It was not.

Q. You have there Mr. Moore's table showing the discharges at Lemont on December 20th, which is I believe approximately 9 miles from the power house?

A. I have such a table.

Q. And according to Mr. Moore's testimony, which you heard this morning, did you not, it was stated that the highest discharge, greatest discharge at Lemont was observed by him at 9:28 or 9:58 in the evening?

A. That is the largest discharge shown in the tables.

Q. Assume that it were shown beyond a doubt that the greatest discharge at the power house during December 20th was at 4:30 in the afternoon, would you wish to modify your conclusion as to the length of time that it would take to establish a uniform flow of 10,000 cubic feet per second through the channel, from a flow of 4167 feet per second?

A. With that assumption, there would be nothing to cause me to change my opinion.

Q. Why not?

A. There appears to be an interval of 33 minutes between five and 5:33 P. M. of that day, on which no observations were taken; and this is about the period at which this discharge corresponding with the flow that you have assumed would reach the Lemont Section.

Q. Then I take it there was no data in Mr. Moore's examination, appearing in Mr. Moore's report, on which you could base a conclusion as to the change of discharge?

A. The interval of time from the power house to the section would not be shown at that particular time. There were other observations, however.

Q. What other observations?

A. There was a sudden break in the amount of discharge on the morning of December 21, which was observed; and there was also another sudden break on December 22.

Q. What time?

A. Shortly after five o'clock P. M.

Q. In the morning or afternoon?

A. P. M.

Q. Referring to table 2, sheet 4, showing the discharges for December 22, doesn't it appear that the maximum, greatest discharge occurred between 5:49 and 6:21, greatest discharge measured at that date?

A. It does.

Q. What streams have you gaged with the current meter, Mr. Ray?

A. I have never made any discharge measurements myself with the current meter.

Q. From whom did you receive instructions with reference to the method of determining discharges of rivers?

A. I have never received any instructions in regard to discharge measurements, except a very brief training that I had in college.

Q. You have made studies of the work of other men, haven't you?

A. I have studied the work of other men.

Q. You studied the work of Mr. Shenehon?

A. Yes, sir.

Q. Mr. Sabin and Mr. Haskell?

A. Yes.

Q. The Haskell Current Meter was used by the Lake Survey when you became Principal Assistant Engineer?

A. It was.

Q. And has been used for several years?

A. We have made very little use of any other meter.

Q. The first gagings that were made on the St. Clair, Niagara and St. Lawrence Rivers were made with the Haskell Meter?

A. They were.

Q. Professor E. E. Haskell, was Principal Assistant then, was he not, of the Lake Survey?

A. The first discharge measurements on the rivers were made before the Lake Survey was a separate office.

Q. I am speaking of the work done by the Lake Survey in 1899?

A. There was no separate office known as the Lake Survey in 1899.

Q. What was Mr. Haskell's position at that time?

A. He was Assistant Engineer of the U. S. Engineer Office.

Q. Was he Senior Assistant?

A. I believe he was, although the work of that office was divided into various departments. The Engineer Office at that time had charge of improvement work at the Soo; on the Detroit River and on Lake Huron.

Q. What did Mr. Haskell have charge of at that time?

A. I believe Mr. Haskell had supervision of the operation under the appropirations for Lake Survey work.

Q. He had charge of the measurements of these rivers, did he not, gaging at that time?

A. That is my understanding. I was not here at that time.

Q. Is there any reason why the elevation at a certain point in the bottom of a stream should control the elevation at another point five feet away.

A. No.

Q. If in a stream 2,000 feet wide, you have located by sounding the position of the bottom at 100 points in the cross section, do you then know the actual elevation of the bottom at 99 other points midway between them?

A. You don't know the precise elevation of the points between.

Q. Is there any reason why the other 99 should give the same average elevation as the original 100?

A. There is a reason why they should give about the same average.

Q. What is that reason?

A. On the law of averages, the 100 points might be assumed to give the same average depth as the other 99. There

is no reason to believe that the other 99 points would be uniformly higher or lower.

Q. Did you ever sweep a river bed?

A. Not in a river.

Q. Did you ever in the lakes?

A. I have.

Q. Have these river beds ever been swept?

A. Portions of them.

Q. And at the gaging sections?

A. I don't recall now that they have.

Q. What is the purpose of sweeping?

A. In the open lake?

Q. Anywhere?

A. The purpose of sweeping is to determine the least depths and also to determine the presence or absence of obstructions between the lines of soundings, or within the area swept.

Q. Do you believe that you can take five years from the period between 1860 and 1874 and have the conditions of local supply on both Lakes Michigan and Huron and on Lake Erie the same as in any other five years selected from the period between 1893 and 1907?

A. I do not.

Q. In the five years selected by you as given in your direct testimony from the earlier years, were they low or high water years?

A. They were low water years.

Q. And to those in the later period, were they high or low water years?

A. They were high water years.

Q. Do you expect the conditions of local supply to be the same in high water as in low water years, on Lakes Michigan-Huron as compared with Erie?

A. The local supplies would not necessarily be the same.

Q. Would variations of the local supply influence the elevations of the lake, mean annual elevation, or the elevations during the open season?

A. The local supply would be one of the elements affecting the elevations of the lakes.

Q. You selected during the earlier period of years 1866, 1868, 1869, 1872 and 1873, did you not, subject to correction?

A. I selected the five years of lowest stage on Lakes Michigan-Huron.

Q. And which were the years mentioned by me in my question were they not?

A. Those years were 1866, 1868, 1869, 1872 and 1873.

Q. And the years selected in the later period were 1904, 1905, 1906, 1907, and 1908, were they not?

A. The years selected out of the later period were 1894, 1904, 1905, 1906 and 1907.

Q. Referring to Williams' Exhibit 34, Table XLVIII, Sheet 1, will you read the precipitations there given for Huron-Michigan basin, as determined by the mean of the precipitations at Milwaukee and Detroit for the years in the first period and tell us what is the average for the five years.

A. The precipitation as shown by this table for the years named are as follows, in chronological order:

33.95
31.08
35.85
29.18
33.31

The mean of which is 32.67 inches.

Q. Referring to the same exhibit and table and sheet, will you read the precipitation of the St. Clair-Erie basin, as determined from the mean of precipitations at Detroit, Cleveland and Buffalo; and I will ask you if the mean is not 37.51 inches?

A. I got a mean of the same, 37.51.

Q. The difference then is 4.84 inches, isn't it?

A. Correct.

Q. Now referring to Sheet 2, of the same table, will you give us the precipitation for the Huron-Michigan basin for the years in your later period and tell us what the mean is?

A. The mean precipitation for Michigan-Huron as shown by this table for the five selected years of the later period, is 30.52 inches.

Q. Referring to the same years in the same table and exhibit sheet, what was the precipitation on the St. Clair-Erie basin for the later period, what is the mean?

A. The mean is 32.67.

Q. What is the difference in precipitation on the two basins?

A. Difference of 2.15 inches.

Q. What would be the effect of an excess precipitation on the St. Clair-Erie basin of 2.69 inches in raising or lowering Lake Erie relatively to Lake Huron? It would raise Lake Erie, wouldn't it?

A. All other things being equal, the additional precipitation on Lake Erie should give a higher stage for that lake.

Q. Would Lake Erie occupy its normal position relative to Lake Huron, or the same position relative thereto, when its precipitation exceeded that of Huron-Michigan by 4.84 inches that it did in a series of years when the precipitation on its drainage area exceeded that of Huron by only 2.15 inches?

A. Assuming that the effect of ice, run-off and evaporation were the same, the increased rainfall on Lake Erie should raise that lake to a higher stage in its relative position.

Q. When you made your comparison, did you assume or did you take into consideration the possible effects of ice?

A. I did not.

Q. Then does your comparison of the two five-year periods show anything conclusive as to the changes in fall between Lakes Huron and Erie, under average conditions?

A. That was taken as simply one method of comparing the lakes. The years were selected merely to get a comparable stage, and I do not believe that this comparison is conclusive. It is simply one of many comparisons that can be made.

Q. It ignores one important element doesn't it, precipitation or local supply on the two lakes?

A. It ignores the causes for the stages, whether those causes were during those current years or preceding those years. It is simply a method of comparing the difference of stages for the same elevation.

Q. Will you state, Mr. Ray, just how, given a number of discharge measurements say of the Niagara River or the St. Lawrence, how do you derive the increment?

A. The discharge measurements are plotted with respect to stage and the increment determined graphically; or it may be a mathematical solution to determine the formula of discharge related to the stage, and increment derived from that formula.

Q. Do you group the discharges with reference to stage, in either process?

A. It is not necessary; it may be done.

Q. What did you do?

A. The discharges have been grouped for a graphical representation of the increment. I believe in all cases—

Q. According to what?

A. Have been grouped according to stage.

Q. According to stage?

A. In the mathematical determination of the formulae, I

believe in all cases the independent observations have been used.

Q. Then an observation made one year might be placed with an observation made another year?

A. Providing the stage overlapped in the two years.

Q. What do you mean by overlapped?

A. If the range in stage during one year passed above or below the limits of the stage during the preceding year, that would be called overlapping.

Q. Now you occasionally take two observations a day, don't you?

A. Or more.

Q. What?

A. Two or more.

Q. And Lake Erie fluctuates or oscillates from time to time during the day, doesn't it?

A. It does.

Q. Several feet at Buffalo in one day?

A. Very seldom to that extent.

Q. But it changes to a considerable extent, does it not?

A. It does.

Q. So that you might take a discharge measurement, say in the morning when the stage was low, and another discharge measurement in the afternoon when the stage was high, might you not?

A. That might occur.

Q. And the discharge measurement made in the morning would be grouped with a discharge measurement made at some other time, say the month before or the year before, when the lake was at the same elevation approximately?

A. If they were grouped with respect to stage that might happen.

Q. And that was the method that was used, was it not, in getting the graphical representation of the increment?

A. It was.

Q. Over what period of time was the lake elevation used with each discharge observation; that is to correspond to each discharge observation?

A. Over the time in which the observations were being made.

Q. That is you would take the mean of the lake stage for the two or three hours that was consumed in making the observation?

A. That was usual. That is a weighted mean; those were weighted means.

Q. You took weighted means, you say. How were they weighted?

A. They were separated by panels, and the result was essentially a weighted mean.

Q. That is you would ascertain the time when you were making your discharge measurement in a certain panel, would you?

A. I believe that is right.

Q. And take the level of Erie in the case of Niagara, for what time during the discharge measurement of one panel, for what length of time?

A. The discharges during the measurement of each panel were referred to the corresponding stages, and that in effect gave a weighted mean for the discharge.

Q. For the time during which you measured that particular panel, or each panel. Is that the idea?

A. That is my understanding.

Q. Now how were they weighted?

A. It was essentially the same as weighting, in using the stages for the separate panels, deriving the discharge separately for the various panels.

Q. Is each panel given an equal weight, or how do you do that?

A. I thought I explained that.

Q. Was the water level during the taking of the discharge measurement of each panel given equal weight?

A. The discharge of each panel was computed with respect to the stage prevailing at the time the measurement of that panel was taken.

Q. In referring your discharge to the lake elevation, what weight was given to the mean elevation during each panel gaging; was it given the same weight or different weights?

A. It is my understanding they were weighted according to the volume of discharge through that panel.

Adjourned to Saturday February 21, 9:30 A. M.

Saturday, February 21, 9:30 A. M.

F. G. RAY resumed the stand and testified further as follows:

Re-direct Examination by Mr. Hopkins.

Q. Mr. Ray, you spoke of some dredging in the St. Clair River, on your cross examination. What ultimate effect do you think this has had or will have upon the regimen of the river?

A. That dredging, as I explained, was all dredging done by private companies for gravel in the upper St. Clair River, and surveys in that locality have shown from time to time that there is no material change, although this dredging has continued for a great many years.

Mr. Adcock: I did not understand. Did you say surveys in that locality?

A. Surveys in that locality. Dredging was continued for many years on the shoal at the mouth of the Black River; a great deal of material was removed, although I am not able to state how much. The surveys have shown that the shoal is not materially different in size now than at the time of the original surveys.

Mr. Hopkins: Q. What is the nature of the excavation in the stream itself. In other words what kind of a hole does it leave?

A. Why the dredging has been largely with clam shell dredges, and it has left sort of pot holes in the bottom of the river, which naturally fill up in a very short time. There is known to be lots of material moving down the river, particularly after Northeast storms in Lake Huron.

Mr. Adcock: Q. You say "known to be." Did you see it, or what information have you?

A. I have observed the material moving there at the head of the river myself during surveys on Corsica Shoal, and these matters have been reported upon by the hydraulic parties that worked on the Upper St. Clair River.

Mr. Hopkins: Q. You spoke in your cross-examination of the fact that there has been no artificial compensation for that dredging. Was there any other kind of compensation?

A. Such as I have just spoken of, the natural compensa-

tion. The river seems to fill up naturally to its normal bed following these dredging operations.

Q. Referring to the reports of 1910 and 1912, which were referred to in cross-examination, will you tell us again a little in detail what that letter Y in your equation represents?

A. Y in the discharge formula for the St. Clair River, as given in the 1912 report, may represent the mean bed of the river. The object is using this method of solution for the discharge equations was to determine a better value for the increment of that river.

As I stated in the cross-examination, there appeared to be some discrepancies between the observations for various years; when solved for a single formula covering the entire set of observations, the residuals were apparently grouped by size or sign for the various years, and showed that these yearly groupings were not directly comparable, for some reason or other.

It was stated in the report that the various values for Y might be considered to represent a change in regimen, although it was realized at the time, and it is believed now, that the difference in the values of Y also includes the errors in gages, the difference that might be shown by different ratings of the meters in the various years, and also includes any difference due to personal equation of the different observers.

Q. Then when questions were asked you in cross-examination in regard to a three per cent. change, was that from the maximum to the minimum, or was that change to the mean?

A. That was the range between the maximum and the minimum. The greatest difference from the mean curve was about 1.7 per cent.

Q. Was it also assumed in those questions that the entire change, or the entire Y, was due to change in regimen?

A. If the measurements during the various years were absolutely correct, the difference in Y would represent a difference in regimen.

Q. But in the hypothetical questions asked you, where there was an assumption that the bed of the river had been raised or lowered, they assumed that the entire value of Y was due to the change of regimen.

Mr. Adcock: I want to object to that question. The question referred to by counsel speaks for itself, as to what was assumed.

A. It is not unreasonable to believe that the difference in Y is largely due to change in regimen, but it may contain differences due to these other causes, which I have stated.

Mr. Hopkins: Take a period of ten or eleven years, and base on the 1912 equation, what change of regimen is indicated?

A. If the value of Y actually represents a change in regimen and nothing else, this change between 1899 and 1910 would be equivalent to a change of .07 of a foot in the mean river bed. This would amount to about three-quarters of one per cent. in the discharge.

Q. Which way was that?

A. The 1910 value would show a higher bed of river than the 1899 value.

Q. And what effect does that have on the discharge?

A. Somewhat lessens the discharge.

Q. In one of the reports, there is some reference to a three per cent. variation. Will you explain how that is?

A. (Referring to same.) In explanation of the statement on page 3013 of Appendix FFF Chief of Engineers Report for 1911, in which it is stated that the observed discharges of 1910, when compared graphically with former values indicate an increase of about three per cent. in the volume of flow through the St. Clair River at mean stage since the determinations of 1899,—'01, I will state, that that is the result of a preliminary comparison. The final reduction had not then been made.

Q. Does it so state in the report that it is a preliminary reduction?

A. It states that a graphical comparison was made with former values and this comparison indicated an increase in flow of about three per cent. The comparison was made by plotting the new observations with respect to the curve determined or published in the 1904 report.

In making the final analysis, it appeared that the observations of the earlier period were not on the same stage as those in 1909 and 1910, and that a line passed through the earlier groups did not strike the more recent observations.

Grouping the later observations to establish a graphical curve through those, this curve was found to come very closely to the center of gravity of the earlier observations. In other words, the two curves were not parallel. In following this analysis, the reason for this appeared to be that there was a constant difference or error between the yearly groups, and

that the formula derived in the 1904 report was not the best derivation of the increment.

In making the new analysis of all of the observations, this apparent difference of three per cent. largely disappeared. There is still left differences between certain years as large as three per cent., as I have stated, between the maximum and the minimum.

Q. How much from the mean?

A. The largest discrepancy from the mean is about 1.7 per cent.

Q. You were asked on cross-examination if any written reports had been made to you, or to this office, in regard to ice conditions in the St. Clair, except those made by Mr. Sabin. What other evidence do you have of retardation of flow due to ice than reports made? What evidence have you aside from current meter measurements of volume of flow?

A. The effect of ice jams on the flow of the St. Clair River was determined by Mr. Sabin in 1901, between January and April of that year. In making this determination, Mr. Sabin found a relation between the discharge under ice effects and the fall at the head of the river. By using this relation and applying it to the gage readings at G. T. R. and M. B. R. gages, for other years, it is possible to determine what the effects have been during such periods. These gage records have been examined for the entire period during which the gage at M. B. R. was in operation, and included the time from 1900 to 1906 inclusive.

The retardation in flow in the St. Clair River during these seven years, when reduced to an average for an entire year are as follows: For the winter of 1899-1900, the retardation is equivalent to a flow of 12,400 cubic feet per second distributed over 12 months.

The next year, this retardation is—

Q. What year was that?

A. 1900-01, is equivalent to 21,000 cubic feet per second for 12 months.

1901-02, is 10,600.

For 1902-03, the records are missing at the M. B. R. gage and it is impossible to determine the ice effects.

1903-04, the retardation is equivalent to 14,200 cubic feet per second for 12 months.

1904-05, the retardation is 20,000 cubic feet distributed over 12 months.

1905-06, is 9,900; or an average for the six years of 14,700 cubic feet per second.

Q. Mr. Ray, is it possible to determine the ice effect from the comparison of the discharges of the St. Clair and the Detroit Rivers in the winter time?

A. It might be possible to determine ice effects if the ice blockades occurred either in one or the other river exclusively, but where there is a possibility of ice blockades in both rivers at the same time, I can see no way of determining what those effects are from the discharge formula.

Q. What is the actual fact in regard to whether or not there is ice effect in both rivers at the same time?

A. It is often reported that ice jams occur in both rivers during the same periods.

Q. General ice conditions exist, do they not?

A. The same general ice conditions would exist on the two rivers; if it was a severe winter, you would expect to find plenty of ice in both rivers at the same time.

Q. Mr. Ray, will you explain a little more in detail, why it is possible to measure a large stream with as great a percentage of accuracy, or greater accuracy than small streams or canals?

A. Some of the sources of error in measuring any streams or canals are constant or nearly so, and the sources of error are generally larger in percentage in a small stream than in a large stream. This is true of the determination of the cross section, and is also true of the determination of the vertical coefficients. In the determination of coefficients in the small streams, it is not possible to get as closely to the bottom in percentage of depth as in the larger streams; and it is therefore impossible to determine the trend of the vertical curve as closely.

Q. You said that your opinion as to the length of time it would take a wave to travel in the Chicago Canal, and the velocity, was based upon Mr. Moore's observations. Will you just explain what observations he made, that you base that on?

A. That opinion was based on the gage records that were made at Lemont and Willow Springs incidental to the work of measuring the flow of the Chicago Drainage Canal, using the time interval between the two gages.

Q. It was not then the time interval between Lemont and the power house?

A. It was not.

Q. Is the maximum flow in that canal the same at Lemont as it was at the power house at the same time, or allowing for the time to travel?

A. Not necessarily so. All observations at Lemont show that the stage continued to fall at Lemont and at Willow Springs after the increased flow had reached there. The flow through the power house for a time would include an additional amount necessary to deplete the storage in the canal between Lemont and the power house, so that the maximum flow through the power house might not coincide with the maximum flow at Lemont, and certainly the two would be different in amount.

Q. Is there any general formula with reference to the travel of wave velocity?

A. I only recall one formula, that given by Merriman, in which the velocity is equal to the square root of g x d, d representing the depth.

Q. What does g represent?

A. Acceleration of gravity.

Q. And from that formula what is the conclusion as to the length of time it would take the velocity to travel from the power house to Lake Michigan as compared with the observations?

A. The two values agree very closely. They are corroborative of each other.

Q. Mr. Ray, you were asked to compare certain years between 1865 and 1875, with certain years since 1890, with reference to rainfall. The rainfall data in the question was taken from Williams' Exhibit 34 in this case. What reliability is to be placed upon the rainfall data back in those early years?

A. The rainfall data for those earlier periods is not understood to be very reliable, and not comparable with the rainfall data of recent years.

Mr. Adcock: I object to that and move to strike out that portion of the answer which states, "understood to be unreliable."

Mr. Hopkins: Q. What is your opinion as to the reliability of it?

A. My opinion is that it is not as reliable as recent data.

Q. What is your opinion as to whether or not it is comparable with rainfall data of recent years?

Mr. Adcock: He has already stated his opinion. He has already compared it.

Mr. Hopkins: He said "It is generally understood." I am asking for his opinion.

Mr. Adcock: He has already stated his opinion. I submit that he has answered the question.

Mr. Hopkins: Answer it.

A. Furthermore, I don't believe that rainfall data at two stations such as Milwaukee and Detroit would represent the actual precipitation on the entire drainage area or the entire lake surface of Michigan and Huron.

Q. How about Detroit, Cleveland and Buffalo as to the precipitation on the drainage area of Lake Erie?

A. That might possibly be somewhat better, but in the former case you have no data for the upper end of the lakes and the rainfall in those regions might be considerably different.

Q. Why did you direct the third or the split section of the Niagara River to be measured last year, Mr. Ray?

A. The question of measuring another section on the Niagara River had been discussed in this office for several years, but the reason for making the measurements this last year was on account of the testimony which had been introduced into this case, with an attempt to throw doubt upon the results obtained by the Lake Survey in the Niagara River measurements.

Q. Any further comment upon the reason for these measurements or the results of them?

A. Another reason for making the measurements was to determine the discharge on a section which was materially different in condition from the sections at the bridge and in the open section; and to verify or determine what possible error there might be in the former measurements.

Q. In the new equations of 1912, how does the volume of flow at mean stage compare with the volume of flow as shown in Complainant's Exhibits 1, 2, 3 and 4, at approximately the mean stage of the observations?

A. There is no material difference in the amounts determined for mean flow or mean stage during the times of observations.

Q. Now the same question only as to increments instead of volume of flow?

A. The increments were changed somewhat for the St. Clair and St. Lawrence Rivers.

Mr. Adcock: Q. Up or down?

A. The increment for the Niagara River was not changed at all. The same equation—

Q. The St. Lawrence River? That was reduced, was it not?

A. The increment for the St. Lawrence River was reduced.

Q. And that for the St. Clair also?

A. Yes, it was.

Q. That was in 1912?

A. The 1912 equation determined smaller increments for St. Clair and St. Lawrence Rivers.

Mr. Hopkins: Mr. Ray, what is the source of your information in regard to the cost of power at Niagara Falls?

A. The price that I named in the direct examination was merely hearsay, and was supposed to represent the price to the large consumers at or in the vicinity of Niagara Falls.

Mr. Adcock: What was that price?

A. $18.

Mr. Hopkins: Q. Didn't the Secretary of War take some bids, if you know?

A. I think the Secretary of War received proposals from various companies by advertisement to import power from Canada. The proposals were received upon a competitive basis, one of the items for consideration being the rates of charge to the consumers. The rates submitted in these proposals by the companies all operating at Niagara Falls were the same as the rates then in existence. I have some of the rates which they submitted at that time. They are public.

Q. What are some of the rates to the consumers in those bids?

A. The rates proposed are rates to so-called small consumers at Niagara Falls. This rate for firm power ranges from $35 per horse power per year, in lots less than 10 horse power, on a 24 hour basis, to $20 per horse power per year for energy of 500 horse power and upwards.

The rates at Buffalo under the schedule of demand rate ranges from $36 per electrical horse power per annum, when not exceeding 100 horse power to $27.50 per electrical horse power per annum when the demand equals or exceeds 500 horse power.

Mr. Hopkins: That is all.

Re-cross Examination by Mr. Adcock.

Q. Do you know of any company that is buying electricity down there, and the price they pay?

A. I don't know any of the rates to the large consumers.

Q. Where was this electricity that you speak of delivered?

A. These are published rates for consumers, small consumers at Niagara Falls and Buffalo.

Q. Where is the power measured?

A. On the consumers' premises.

Q. That is after all the transmission expense and everything like that has been taken care of?

A. Yes.

Q. Don't you know as a fact that the Ontario Paper Company is producing horse power from the Ontario Power Company at an average price of $8 per horse power per year?

A. I don't know that.

Q. Was this 24-hour service?

A. It was so stated on the schedule of rates.

Q. To whom was this horse power that you speak of sold for $18 per horse power per year?

A. I have been told that there are contracts in existence at Niagara Falls with the large consumers.

Q. Do you know of any?

A. I do not.

Q. You do not know of anyone buying it at that price?

A. No.

Q. Were any of these proposals which the Secretary of War invited accepted?

A. They were not. These rates that are quoted here are rates that are in existence in Niagara Falls and Buffalo, and power is being sold at those rates.

Q. That is measured at the consumers' premises, is that right, and those are small consumers that you mentioned there, aren't they?

A. They are.

Q. What was the average percentage of the effect of six years' record of ice? It was about eight per cent., wasn't it, as you stated?

A. About that.

Q. This was based on Mr. Sabin's report, was it not?

A. This was based on the relation between discharge and fall at the head of the river, as obtained by Mr. Sabin in his discharge measurements.

Q. Has anyone else made any computations of ice effects, comparing it with Mr. Sabin's report?

A. Mr. Russell made some computations of ice effects.

Q. Who is Mr. Russell?

A. Mr. Russell is an assistant engineer in the Lake Survey office.

Q. How long has he been with the Lake Survey?

A. He has been with the Lake Survey for a great many years. I would have to look up the record to give a definite answer.

Q. Has he been connected with the Lake Survey longer than anyone else who has testified in this case?

A. He has.

Q. He is very familiar with conditions around this locality, and on the St. Clair and Detroit Rivers, isn't he?

A. I am not sure that he is familiar with the conditions. He is familiar with the records of the office.

Q. And various reports, records of measurements and computations and so forth that have been made?

A. I judge that he is familiar with those.

Q. How do his computations compare with Mr. Sabin's referring to page 4107 of the report of 1904, Chief of Engineers?

A. The ice effects determined by Mr. Russell are for the year 1901, and are smaller than those determined by Mr. Sabin, except for the month of May.

Q. What is the average for the five months?

A. The average for the five months, as determined by Mr. Sabin, is 49,620 c. f. s., and as determined by Mr. Russell is 26,930; the difference between the two being 22,690 cubic feet per second.

Q. What percentage of Sabin's is Russell's?

A. About 54 per cent.

Q. If Sabin's per cent. was 8 per cent., then Russell's was about 4 per cent., wasn't it?

A. About that.

Q. This report of Mr. Russell's, and the computations that he made, were after those of Mr. Sabin, were they not?

A. They were.

Q. And after certain discharge measurements were made on the Detroit River?

A. They were.

Q. And Mr. Sabin did not have before him, at the time he made his computations, the records of the discharge measurements on the Detroit River, did he?

A. Mr. Sabin did not need to have the records of the Detroit River.

Q. I am asking you the question. Will you kindly answer it?

A. He did not have the records.

Q. Mr. Russell's report was approved by the principal assistant engineer of the Lake Survey, wasn't it?

A. I don't know just how fully that report was approved. I presume it was approved or it would not have been published.

Q. Well, the Chief of Engineers must have approved it, or he would not have published it, would he?

A. That is a report of this office, and it would be published—

Q. If it were approved by the principal assistant?

A. If it were approved by the principal assistant.

Q. So the principal assistant must have approved it. Isn't that true?

A. I presume it was approved.

Q. That was the custom in the office, wasn't it?

A. That was the custom.

Q. Customary to approve?

A. It was customary. It was understood that the report was approved.

Q. Do the gage records indicate the presence of ice jams in the Detroit and St. Clair Rivers?

A. I stated in the re-direct examination that they might indicate the ice effects, but not necessarily so.

Q. That is what gages?

A. The relation between the gage readings at Harbor Beach, St. Clair Flats and Cleveland.

Q. On how many occasions in the last ten years have gorges occurred simultaneously on the two rivers, the Detroit and St. Clair Rivers?

A. We have no definite records.

Q. If the discharge capacity be reduced by say 8 per cent., the increment must be reduced by less than that per cent., according to what you said yesterday, so that the effect of this ice on the increment would be more than 8 per cent., and according to Mr. Russell's figures is probably about 4 per cent. Isn't that true?

Mr. Hopkins: That is the total increment for the year.

Mr. Adcock: Yes.

A. The retardation of flow might be eight per cent., and the effect on the increment greater than eight per cent.

Q. Will you explain how?

A. The mean increment for the year, taking into account the ice effect would depend upon the increment during the time that the rivers were partly blockaded. If the increment

during the open season, say eight months, was 22,000 and the increment for the remaining four months of the year was 10,000, the mean increment for the year would be about 18,000, which is less than the open season increment by upwards of 20 per cent.

Q. What decrease of discharge would you have to have, to compare with an increment of 10,000?

A. I can't see that the increment during the ice blockades has any relation to the amount of retardation of flow.

Q. Will you state why you believe that?

A. As an illustration, the effect of ice during four months of the year might possibly be the same, regardless of the stage on Lake Huron; in which case the increment of flow for those four months would be zero, and would bear no relation to the amount of retardation.

To make my meaning clear, I will add that I mean by that that the amount of water flowing past this blockade of ice is assumed to be the same regardless of the stage.

Q. Could that possibly exist?

A. It is possible but not probable. It is simply an illustration to show that the increment during the winter months bears no relation to the amount of retardation.

Q. Do you mean to say that given a certain ice jam and Lake Huron rises a foot, there would be no change in the flow through the St. Clair River?

Mr. Hopkins: He didn't say that.

A. I do not mean to say that, but the increment of flow would not be the same as during the open season.

Q. Did you assume that Lake Huron remained at the same stage during the ice jam, during the time of the ice jam, when you said the increment would be zero?

A. In that illustration, I was assuming that the ice jam for two different stages of Lake Huron allowed the same amount of water to pass, which is possible but not probable.

Q. That is the same ice jam, or a different ice jam? In other words, is it your proposition that if Lake Huron during this period when there was an ice jam rose a foot, there would be no increase of flow through the St. Clair River?

A. That assumption could be made for the same ice jam, or it could be made for ice jams of different years.

Q. You mean that it is probable that the ice jam would increase as the lake level rose, so that there would be no increase in flow? I just want to get what you mean, Mr. Ray. You say there would be no increment of flow?

A. I do not intend to claim that the amount of water flowing through the St. Clair River would be the same regardless of the stage of Lake Huron. The illustration that I gave was merely to show that there was no relation between the increment during the ice jams and the stage on Lake Huron.

Q. But I understood you to say that during ice jams, it would be possible that the increment would be zero. If the increment were zero, it would necessarily follow there would be no increase in discharge for a rise of a foot in Lake Huron?

A. I believe that the increment would be something more than zero, but it would not bear any relation to the amount of retardation.

Mr. Sabin in his report states that the increment during his observations was more or less indeterminate; that as near as he could determine during that period the increment was about 10,000.

Q. That was because of the change in the jams or change in retardation?

A. He simply found that during the ice stage there was more water flowing down the river past the ice blockades, and that that was approximately 10,000 cubic feet per second per foot of rise.

Q. Now assuming that at a particular instant while there was an ice jam, Lake Huron should rise a foot, would there be any increase in the discharge?

A. The measurements indicated that there would be.

Q. Did the measurements cover a condition of that kind? Did the measurements of Sabin cover a condition of jam and a rise or fall of lake as assumed in the question?

A. The measurements were taken during a range in stage on Lake Huron, and while this range was not large enough to give a definite determination of the increment during the period of measurements, the nearest indication was that the increment was about 10,000 cubic feet per second during those measurements.

Q. Weren't the ice jams changing during the course of these observations?

A. They probably were.

Q. And the section was therefore changing in its carrying capacity?

A. Not the section on which the measurements were taken.

Q. Well, say at the jam?

A. He did not measure at the jam.

Q. And the discharging capacity of the river as a whole was changed by the jam?

A. It was.

Q. Now the change in the discharging capacity would make a change in the increment, wouldn't it?

A. Probably would.

Q. When you say "probably," does that mean that you have a doubt?

A. The determination of increment on the observations of Mr. Sabin covered the full period of the time of those observations and naturally represented the increment during the mean condition.

Q. (Question read.) Now, will you direct your attention to the question, as to whether you have a doubt?

A. The change in the carrying capacity of the river would necessarily make a change in the increment.

Q. Would the proportionate change in increment be as great or greater than the change of discharging capacity of the river?

A. That is indeterminate from the data.

Q. That is your opinion it is indeterminate?

A. That is my opinion, it is indeterminate from the data.

Q. In your discussion of the equation in which the value of *Y* was given as the elevation of the bed of the river, do you wish us to understand that the term "change of regimen" is synonymous with the term "change of the bed of the river"?

A. Generally speaking it is.

Q. When you say "generally," what do you mean. Can you give us a more definite idea?

A. This equation is purely empirical and the value of *Y* in that equation may represent the mean river bed, may be considered to represent the mean river bed, and a change in the value of *Y* would therefore be considered a change in regimen.

Q. If there were during the day a maximum discharge at a certain time at the power house on the end of the drainage channel, ought there to be at some time later a maximum discharge at the section at Lemont, as compared with other discharges at Lemont during the day?

A. If there was a sharp peak in the load in the power house at Lockport, there would be a peak on the discharge at Lemont sometime later.

Q. Ought they to be equal in amount?

A. Not necessarily equal.

Q. What do you mean? The discharges would not be equal in amount?

A. The maximum momentary discharge would not be the same as the maximum momentary discharge through the power house.

Q. Would it be greater or less?

A. If this peak load were sharp and the load were suddenly withdrawn again, the discharge through the power house would be greater than the maximum flow past Lemont.

Q. Suppose that Lake Michigan should suddenly go up two feet and then recede, would the discharge at the mouth of the Chicago River coincide with the discharge at Lemont at a later time; the discharge at the power house remaining the same during the period?

A. If the discharge at the power house remained the same, —I don't understand your question.

Q. No, if Lake Michigan should go up two feet and should then recede, would the discharge at the mouth of the Chicago River coincide with the discharge at Lemont at a later time, assuming that the Bear Trap Dam or the regulating works at the end of the canal were unchanged during the period of time?

A. I would say that the maximum discharge at Lockport would not be as great as the momentary maximum flow into the canal at Chicago.

Q. If the water were free to escape over a weir at Lockport as soon as there was a rise in the canal at that point, a rise of the water level in the canal at that point, would that make any difference in your answer to the preceding question?

A. It would not.

Q. Assuming that Lake Michigan-Huron should suddenly rise three feet and then recede by the same amount, would the maximum discharge at the head of the river coincide with the discharge at the Dry Dock Section at a later time on the St. Clair River?

A. The wave proceeding down the river from a sudden fluctuation on Lake Huron would be somewhat flattened out, and while the amount of water entering the head of the river must necessarily pass the Dry Dock, the maximum velocity would not represent the maximum inflow from Huron by a small difference.

Q. You spoke of an equation here, V = square root of g $\times$ d. Just what does that mean; I did not quite understand it from your redirect examination?

A. That is a theoretical equation representing the velocity of tidal waves.

Q. Did you use that equation in working out the conclusions with reference to the establishment of a uniform flow of 10,000 cubic feet per second through the canal at all points, from a flow of 4,167 cubic feet?

A. I did not.

Further Re-Direct Examination by Mr. Hopkins.

Q. Mr. Ray, you were asked a question, assuming that there was a sudden rise on Lake Huron and then a sudden drop, whether or not the entire effect would be felt at the Dry Dock Section.

Q. Do any such conditions as are assumed in that question exist in fact?

A. Not to my knowledge, and I don't believe it is possible.

Q. Taking the conditions as they do exist, what would your opinion be as to the same question, that is the effect of elevations of Huron on the flow at Dry Dock Section?

A. The sudden fluctuations on Lake Huron are a great deal less than those in the hypothetical question, and occur both in the general manner stated and also in the inverse. That is that there is a drop and then a rise during the observations, so that the effect of relating the discharges to the gage heights at the head of the river would be compensating.

Q. Yesterday you were asked certain questions about change in flow due to elevation in the bed of the river. It was assumed in all those questions that there was no change in the width. That was as you understood it?

A. It was.

Q. Is that comparable with obstructions by ice as they exist?

A. It is not.

Q. Why?

A. For the reason that the ice blockades may and generally do narrow the discharging section of the river.

Q. How about surface obstructions in the ice conditions, the ice cover?

A. There is a retardation of flow due to ice cover, the

under side of the ice causing friction and consequent retardation.

Q. Now, you say that during the ice period, the increment is indeterminate? With reference to the increment in the open season, is it greater or less?

A. It must necessarily be less.

Q. You mean less under ice conditions?

A. Under ice conditions, yes.

Q. Did Mr. Russell make any observations himself in regard to ice conditions?

A. Not to my knowledge.

Q. He used Sabin's observations, didn't he? Just what was Mr. Russell's method, the results of which are reported in that 1904 report?

A. The ice effects as determined by Mr. Russell were computed from the discharge equations of the two rivers, the effect being determined by the differences as shown by the gage heights, and the discharge equations.

In Mr. Russell's comparison shown in the 1902 report, he has compared the ice effects as determined from the discharge equation with those given in the 1902 report by Mr. Sabin, which effects determined by Mr. Sabin were actually measured and were not theoretical.

Q. Are there any indeterminate elements in the winter determinations made by Mr. Russell?

A. If I understand your question, the ice effects as determined by Mr. Russell depend upon gage relations introducing the stage of water in Lake St. Clair and comparing the discharges as determined by that gage for the Detroit and St. Clair Rivers. If there was any retardation or blockade in both rivers at the same time, his derivation in this method could not be correct.

Q. As a matter of fact didn't he use open season equations for this determination of the flow of the two rivers?

A. He did, and in that method assumed that one or the other river was flowing freely and openly.

Q. What knowledge have we of the equation of discharge of the Detroit River under ice conditions?

A. None whatever.

Further Re-Cross-Examination by Mr. Adcock.

Q. Who was the Principal Assistant Engineer when Mr. Russell made his report?

A. Mr. E. E. Haskell.

Q. How many observations did Mr. Sabin make?
A. I derive from the records that Mr. Sabin made 61 discharge measurements during ice conditions.
Q. What time was occupied in making each discharge measurement?
A. It would take a week to answer that.
Mr. Hopkins: Objected to on the ground that the witness did not make them.
Mr. Adcock: Q. What was the average time?
Mr. Hopkins: If you know of your own knowledge?
A. I don't know of my own knowledge. It is a matter of record.
Q. Have you any records of it?
A. The records of Mr. Sabin's measurements are in the office.
Q. Would it take two days to make each discharge measurement?
A. No.
Q. Would it take one day?
A. I presume not.
Q. Would it take 12 hours?
A. I don't know.
Q. Well, would you say more or less than 12 hours in your opinion?
A. I should say less than 12 hours.
Q. As much as six hours less than 12 hours?
A. I have already stated that I don't know.
Q. You are Principal Assistant Engineer, and I am asking for your judgment as to how long you think it would take Mr. Sabin under those circumstances to make a discharge measurement.
Mr. Hopkins: That is objected to as incompetent and immaterial, how long it would take Mr. Sabin to do anything. You do not need to answer that, anyway.
Mr. Adcock: Go ahead.
A. I am not familiar with the conditions under which Mr. Sabin had to work during the ice measurements.
Q. Have you made any computations yourself from the records that Mr. Sabin has made?
A. I have not.
Q. Then you don't know the conditions, actual conditions under which Mr. Sabin made those measurements, do you?
A. Only so far as they are stated in his reports.
Q. In the report of the Chief of Engineers?
A. Yes.

Q. You don't know what length of time was covered in making a single discharge measurement?

A. That is a matter of record in the office.

Q. I say you do not know personally?

A. I do not.

Q. How many discharge measurements were taken each month during the period of ice conditions mentioned?

A. Ten measurements were taken in January, 16 in February, 21 in March and 14 in April, all 1901.

Q. Do you consider that the conditions would be favorable for making discharge measurements during the winter of 1900-'01, in the month mentioned?

A. I know of no reason why they were not favorable.

Q. Well, compare them with the conditions in the open season?

A. I see no reason why the results should not be good. The conditions under which the work was performed was less favorable.

Q. Although you did not know the conditions?

A. I do not know them, no.

Q. How many times has the St. Clair River been measured in open season; I mean years, how many different years were series of measurements made?

A. Seven years.

Q. There was considerable discussion about the effect of ice, wasn't there, at the time Mr. Sabin made his measurements?

A. I was not here at that time.

Q Well, the reports of the Chief of Engineers show that, don't they? Mr. Sabin made a report on this; Mr. Russell made a report about it, and it is referred to in various reports and in this testimony.

A. It has been, yes.

Q. No other discharge measurements of the St. Clair River during ice conditions have been made, except those of Mr. Sabin's, have there?

A. Not to my knowledge.

Q. You say that the total reduction discharge of the St. Clair River, during the five months mentioned in the winter of 1901, January, February, March, April and May, was approximately 50,000 cubic feet per second, wasn't it? If the flow of the St. Clair River were retarded in that way, it would raise Lake Huron, would it not?

A. It would.

Q. And lower Lake Erie, wouldn't it?

A. It would for the time being, yes.

Q. How much would Lake-Michigan-Huron be raised; how much would Lake Erie be lowered?

A. If ice jams such as occurred in the winter of 1900-1901 continued each winter indefinitely, the effect—

Q. No, I think the question is, Mr. Ray, as to what was the effect in 1901 upon Lake Erie and Lake Huron of the retardation mentioned for those months?

A. The backwater effect of the ice jam of 1900-'01 on Lake Huron would be about four inches.

Q. How do you compute that?

A. The retardation of flow shown by Mr. Sabin is equivalent to a retardation of approximately 21,000 cubic feet per second for a year; and at the end of twelve months, about 44 per cent. of the backwater effect would have been consummated.

Q. How much would have been consummated at the end of six months, say on June 1st, 1901?

A. .36 of a foot.

Q. Michigan-Huron would be raised .36 of a foot?

A. That would be the tendency, due to the ice effect.

Q. That would be about how many inches?

A. It would be a little over four inches.

Q. How much would Erie be lowered at that time?

A. The effect on Lake Erie at the end of a year—

Q. I think I asked the question say June 1st?

A. July 1st, you stated.

Q. June 1st, I think?

A. You want it for June 1st?

Q. June 1st.

A. The lowering effect on Lake Erie considering that the flow in the Niagara River is not seriously obstructed by ice during any of the winter months would be 16 inches approximately.

Q. How about 1901?

A. I understood you asked for July 1st on Lake Michigan.

Q. I asked for June 1st on both?

A. The rise on Lake Huron on June 1st would be about 5½ inches.

Q. And the lowering effect of Erie would be how much?

A. Sixteen inches.

Q. On June 1st?

A. It is subject to uncertainties due to ice effects in the late winter on both the Niagara and the St. Clair outflow.

Q. How great is the result you reached in percentage, what percentage of accuracy?

A. I would consider that those amounts were subject to inaccuracies of 20 or 25 per cent.

Q. The error might be either way?

A. It might be.

Q. Now, you are considering the actual conditions as determined by Mr. Sabin, are you not, in his report for the month that he measured?

A. I am.

Q. Will you turn to Mr. Sabin's report, and I will ask you to examine that report and state the amount Huron is raised and the amount Erie is lowered according to that report during the months mentioned for 1901?

A. I do not find that Mr. Sabin has made any statement here regarding the effect at any stated time, such as June 1st.

Q. Don't you find on page 2837, Appendix EEE, Report of the Chief of Engineers for 1902, under the heading "Difference or Effect of Ice for the Months of January, February, March, April and May, 1901," that Lake Michigan was raised during January .06, during February .18, March .11, April .14, May .02, making a total of .52 of a foot; that the depth of Lake Erie being minus was lowered in January .28, February .81, March .51, April .62, May .11, which, if added up, would make a total of 2.33 feet? The figures that I read are from Mr. Sabin's report with reference to his observations during the ice conditions in 1901, is that correct?

A. Those effects are the immediate effects and are not the effects that would be shown on June 1st or any time after the period in which the ice effects occurred. The increased stage caused by the ice on Lake Huron would cause a temporary increase of flow, which would tend to bring back the normal stage on Lake Huron. The same would be true on Lake Erie. Conversely the decreased flow of Niagara River due to the decreased stage would allow Lake Erie to fill again, so that the effects on June 1st would be about as stated.

Q. Then you disagreed with Mr. Sabin's statement?

A. I do not. The backwater effects shown by Mr. Sabin are not intended to represent permanent effects.

Q. Where is it so stated in his report?

A. I don't know that he stated that.

Q. What was the mean elevation of Huron in December, 1900?

A. The elevation of Lake Huron as observed in December, 1900, at Harbor Beach was 580.46.

Q. What was the mean elevation of Erie during the month?

A. 571.45 at Cleveland.

Q. What is the difference?

A. The difference is 9.01 feet.

Q. What was the mean elevation of Huron during the month of June, 1901?

A. 580.91.

Q. And the mean elevation of Erie for the same month?

A. 571.72.

Q. What is the difference?

A. 9.19 feet.

Q. Take the same for May also, Huron and Erie and the difference?

A. The elevation of Lake Huron in May, 1901, was 580.81. Lake Erie in the same month was at an elevation of 571.31. The fall between the two lakes was 9.50 feet.

Q. Take November, 1900?

A. In November, 1900, the average monthly elevation of Lake Huron was 580.66 and of Lake Erie was 571.49. And the fall between the two lakes was 9.17.

Q. According to the actual elevations of Michigan-Huron and the elevations of Erie in the records which you have there, how much did Erie fall between January 1st, 1901, and June 1st, 1901?

A. The water levels of Lake Erie rose about .12 of a foot from January 1st to June 1st.

Q. It rose?

A. Yes.

Q. How many inches is that?

A. 1½ inches.

Mr. Adcock: I think that is all, Mr. Ray.

Further Re-Direct Examination by Mr. Hopkins.

Q. Mr. Ray, suppose there had been no ice effect during the time mentioned in the previous questions from between January 1st, 1901, and June 1st, 1901, what would have been the elevation of Lake Erie as compared with what it was at the time?

A. The elevation of Lake Erie would have been something over a foot higher on June 1st than it actually was, if it had not been for the ice effect.

Q. In answering the question as to what increased elevation there would be in Michigan-Huron, due to the ice effect from the data that you have, did you take into consideration local supply of Huron and Michigan?

A. I did not. The statement of ice effect as given by me was intended as the backwater effect from the ice, and this effect would be to make Lakes Michigan-Huron higher than it would have been without the backwater. The actual change is not represented by the figure given.

Q. And was not intended to so represent the actual figure?

A. It was not intended to represent the actual change in the elevation of Lakes Michigan-Huron.

Q. And as to the effect of the ice on Lake Erie during that year, did you take into consideration local supply on the Lake Erie basin, including Lake St. Clair?

A. I did not. The value that I gave for the lowering effect on Lake Erie of the ice in the St. Clair and Detroit Rivers was simply the effect of ice and did not consider the local supply and did not consider the normal change in the elevation of the lake.

Q. Between January 1st and June 1st, the lake does normally rise, doesn't it, speaking of Lake Erie?

A. The average curve for Lake Erie does so rise between January 1st and June 1st.

Q. In your judgment is that due to local supply?

A. It is.

Q. How about the increased flow from Lake Huron after the ice has gone out?

A. There would be an increased flow due to the ice stage in Lake Huron. The effect of this increased flow would be to draw down the elevation, the abnormal elevation which had been caused by the ice.

Q. Is it your present opinion that Mr. Sabin's results as to ice effect are correct, so far as the volume of flow is concerned?

A. I believe they are so far as the data warrant.

Further Re-Cross-Examination by Mr. Adcock.

Q. Doesn't Mr. Sabin's figure show a retardation of flow into Erie to the effect of about 2.33 feet of lowering of elevation on Erie?

A. The effect on elevations on Lake Erie would be about 2.33.

Q. What would be the rainfall on the Erie basin to produce a run-off or an increase of local supply, so that Erie would raise 2.45 feet?

A. On what assumption were those figures given?

Recess to 2:45 P. M.

After Recess 2:45 P. M.

F. G. RAY resumed the stand and testified further as follows:

Mr. Adcock: (Question read as follows: "What would be the rainfall on the Erie basin to produce a run-off or an increase of local supply so that Erie would raise 2.45 feet") Assuming no change in the discharge of outlet or inlet, that is assuming that there is no change, no flow?

A. A depth of 2.45 on Lake Erie as I compute it is equivalent to a rainfall over the entire land and lake drainage basin of Lake Erie of about 7¾ inches.

Q. That is on the assumption that all the precipitation went into the lake; that amount went into the lake?

A. It is, yes.

Further Re-Direct Examination by Mr. Hopkins.

Q. Mr. Ray, do you want to explain one of your answers in regard to that 2.33? Just read the question and answer.

(Question and answer read as follows: "Doesn't Mr. Sabin's figures show a retardation of flow into Erie to the effect of about 2.33 feet of lowering of elevation on Erie? A. The effect of elevations on Lake Erie would be about 2.33.")

A. In further explanation of what that 2.33 is, I understand it to be the depth of water over the surface of Lake Erie that is equivalent to the retardation as measured by Mr. Sabin during the five months, in 1901.

SHERMAN MOORE, a witness called in rebuttal on behalf of the Government, having been previously sworn, testified as follows:

Direct Examination by Mr. Hopkins.

Q. Mr. Moore, you have been sworn, and have testified in this case before, haven't you?

A. I have.

Mr. Austrian: When was that?

A. That was in May, 1909.

Mr. Hopkins: Q. Since then what further qualification have you had in regard to your work as an engineer?

A. Since that time I have been employed on the Lake Survery, in charge of field parties and general survey work, and also in some hydraulic work. In 1909 I made measurements in the canal of the Niagara Falls Power Company to calibrate the turbines under various gate openings and determine the amount of power which they could develop under varying conditions, without exceeding the amount of water allotted by the Secretary of War.

I also made measurements in the canal of the Hydraulic Power Company at the same time. In the fall of 1909 I made discharge measurements in the St. Clair River, and in that winter reduced all of the velocity co-efficients for Section Gorge.

In 1910, I made measurements during May and June on the St. Clair River on both Section Gorge and Section Dry Dock, located and laid out the sections in the Delta and made some measurements on them.

In December, 1911, I made measurements in the canal of the Hydraulic Power Company for the purpose of determining the amount of power which they could develop without exceeding the amount of water specified by their limitations.

In December, 1912, I made measurements in the Chicago Drainage Canal at Lemont.

Q. 1912 or 1913?

A. 1913. During the winter of 1912 I made a complete re-reduction of all discharge observations of the Lake Survey, deriving new formula where it seemed necessary.

Q. I believe you have already testified that you made certain measurements in the Niagara River in 1907 and 1908?

A. I have.

Q. Any further measurements, particularly with reference to the St. Lawrence?

A. I made measurements on the St. Lawrence River in 1908; that was covered by my previous testimony.

Q. Now, in this work you say you did in 1912 of re-computing the discharge formula for the rivers, just give that a little bit more in detail, what you did?

A. I took up each of the rivers connecting the Great Lakes; examined all of the observations for possibilities of error, and made some changes and alterations in gages and meter readings, which seemed indicated by the observations and by our further knowledge of the subject, and wherever necessary I derived new equations expressing the law of flow in terms of the controlling gage.

Q. What result did you get with reference to the increment at Niagara?

A. The increment of flow on the Niagara River was not changed by the new reductions.

Q. What changes did you make if any in the gages at Niagara, or rather the Buffalo gage?

A. There were no changes whatsoever in the controlling gages on the Niagara River.

Q. About the rating of the current meter, what have you to say?

A. Those were not changed.

Q. The cross sections?

A. The cross section was not changed from that determined in 1907. The observations made in 1907 and 1908 appeared to fall exactly on the line determined in 1906, and no changes whatsoever were indicated as being necessary in the equation of 1906 to express the true relationship in 1912.

Q. What was the purpose of these further measurements that you have mentioned, and these new computations, that is checking over the computations?

A. The purpose of the measurements was to determine whether or not there had been any change in the regimen of the river. The purpose of the reduction was to get for our office record a complete and systematic classification of the various data, a comprehensive treatment of the whole subject.

Q. In cubic feet per second, what is the increment of the Niagara River, as finally determined by you?

A. Between 21,000 and 22,000 cubic feet per second.

Q. Have you examined Ray's Exhibits 1, 2 and 3 of this date?

A. I have.

Q. Did you hear Mr. Ray's testimony?

A. I did.

Q. Do you concur in the conclusions reached by Mr. Ray in regard to those exhibits?

A. I do.

. If not, in what respect do you differ?

A. I concur with Mr. Ray in his testimony.

Q. What effect, in your opinion, do those exhibits have upon the increment as derived by you at Niagara?

Mr. Adcock: Or determined, you mean?

Mr. Hopkins: Yes, the increment as determined?

A. They are an excellent corroboration of the increment as determined by the observations with respect to the Buffalo gage.

Q. Those exhibits eliminate the Buffalo gage, do they?

A. They eliminate the Buffalo gage.

Q. Now give us specifically any further conclusions that you have reached in regard to the St. Clair River?

A. I made measurements of flow on the St. Clair River in 1908, '09 and '10, establishing a new section; and in the spring of 1911 I established the Third Section in the Delta. The agreement between the sections, as I know it, is very close.

Q. Within what per cent.?

A. I believe within 2 per cent.

Mr. Adcock: Q. What agreement, cross section agreement?

A. The agreement of the discharge, the mean discharge, and there is no apparent discrepancy in the increment of flow by the upper two sections. The observations on the lower section were not sufficient to determine an increment. They do not cover a great enough range of stage.

Q. What is your conclusion as to the increment of the St. Clair?

A. The latest reduction by the Lake Survey shows an increment at mean stage of about 21,000 cubic feet per second. That, in my opinion, may possibly be in error by as much as 20 per cent.

Q. On what side do you think that error would occur?

A. In my opinion it is more likely that the increment derived by that equation is too large.

Q. Did you derive an increment from your measurements at the Gorge Section?

A. I derived an approximate increment in the winter of 1909, before we had the present number of observations on that section. The observations were not sufficient to derive

the increment with accuracy, but showed an increment between 18,000 and 19,000 cubic feet.

Q. What effect, if any, have your later observations had upon that increment?

A. There has been no reduction of those observations by themselves, and I could not say what effect the further observations had upon the increment.

Q. What in your opinion is the maximum possible error in that increment that you have just given?

A. Not to exceed 25 per cent. maximum possible error.

Q. What do you think the probable error is?

A. I stated about 20 per cent. That statement of 20 per cent. as a probable error is not technically correct. The term "probable error" is not used mathematically.

Q. Give us, then, the range, what is correct, the range in feet; what would be the maximum and the minimum increment?

A. I believe personally that the increment in the St. Clair River lies between 17,000 and 22,000.

Q. Now, Mr. Moore, what increment did you derive for the St. Lawrence River?

A. About 23,000 cubic feet per second.

Q. For what lake stage is that?

A. That is for stage of 245 feet on Lake Ontario, by the Oswego gage.

Q. Is that mean?

A. Somewhere near it, I think.

Q. What is the increment for a foot lower elevation?

A. 22,000.

Q. In your opinion is the increment of these rivers more correctly represented by a curve, or a straight line?

A. I think there is very little difference between the accuracy of a straight line and a curve. One seems to represent the law of flow about as well as the other.

Q. Within what degree of accuracy do you think the volume of discharge of the three rivers has been measured, taking first the St. Clair River?

A. For the St. Clair River I should say that we knew the volume of flow at the stage representing the mean of the observations within 1 per cent.

Q. Now the Niagara?

A. For the Niagara River, probably within ½ of 1 per cent.

Q. The St. Lawrence?

A. For the St. Lawrence River, within 5 per cent.

Recess to 2:00 P. M.

After Recess 2:00 P. M.

SHERMAN MOORE resumed the stand and testified further on direct examination as follows:

Mr. Hopkins: Q. Mr. Moore, what is your opinion as to the degree of accuracy with which large streams can be measured?

A. I believe large streams can be measured with an accuracy of at least 1 per cent.

Q. In arriving at your conclusion, what specific things do you take into consideration, as for instance cross section?

A. The cross section of a large stream can be determined accurately within ½ of 1 per cent. The velocity co-efficients can be determined within 1 per cent. The velocities, absolute velocities, are practically exact.

Q. How are they determined?

A. With the current meters.

Q. In the measurement of these streams how many meters were used?

A. In the more recent practice of the Lake Survey, it has been customary to use four meters.

Q. Will you explain just how you use them, and how they are rated and checked and so on?

A. Each meter previous to the observations, and at short intervals throughout the observations, is rated carefully on a still water base. The meters are watched very carefully throughout the observations in order to detect any changes from the rating; and there is a systematic interchange of meters in the work, whereby any little eccentricities in individual meters are eliminated from the mean result.

Q. How frequently are ratings made?

A. It has been the practice in more recent work to rate the meters on an average of about once a month.

Mr. Austrian: Will you ask what he means by the more recent work?

Mr. Hopkins: Q. What do you mean by the more recent work?

A. The work since 1906.

Q. Isn't that also true as early as 1900?

A. I believe that the ratings in 1900, and those about that time, were not quite so frequent. There were, however, very frequent still water ratings made.

Q. With reference to the accuracy of current meter meas-

urements, did you make any tests in the power canals at Niagara?

A. The canal of the Niagara Falls Power Company was measured in two sections with an agreement of ½ of 1 per cent. between the two. The canal of the Hydraulic Power Company was measured in two sections, with an agreement of less than 2 per cent.; and in addition there have been measurements made in the penstocks of the turbines with a Pitot tube, which have checked the current meter measurements.

The efficiencies of the turbines were determined originally by current meter measurements in the canal, and later Pitot tube measurements in the penstock of the turbines were made, as a comparison of the two methods. The check was exceedingly good, about 1½ per cent., I think.

Q. Which was higher?

A. The volume of flow by the current meter was the largest.

Q. The two different sections that you checked, the measurements were made with the current meter?

A. On both sections.

Q. And then a check with this Pitot tube?

A. Yes.

Q. Do you know how many horse power per cubic foot per second on the electrical switchboard are generated at the Hydraulic Power Company's plant, say power house number 3?

A. I have no figures which would show the number of horse power generated by one cubic foot in power house number 3. In the two power houses, numbers 2 and 3, the Hydraulic Power Company develop about 19.2 horse power per cubic foot of water. The efficiency of power house number 3 is very much higher than that of power house number 2; and it is probable that the horse power per cubic foot would be considerably larger in that power house, although I have no figures to show it.

Q. Did you yourself make any soundings in the Niagara River at the Bridge Section?

A. I made soundings at the International Bridge, in spans 1, 2, 3 and 4.

Q. Did you find any evidence of a boulder strewn bottom?

A. There was no evidence whatsoever shown by the soundings. The soundings ran uniformly, and indicated an absolutely smooth, hard bottom.

Mr. Austrian: Q. In what year were those soundings made?

A. I think it was 1907.

Q. Do you know anything about the bottom on the Canadian side, span number 8?

A. The bottom of the river is visible in spans 8 and 9 on the Canadian side, and consists in smooth bed rock limestone rock in place.

Q. What is the nature of the bottom in spans 1 and 2?

A. In spans 1 and 2, the bottom is largely composed of silt.

Q. What is the nature of the bottom of the river further upstream, say at the Buffalo water intakes?

A. That is ledge rock.

Q. Do you know of a certain part of the Niagara River where the bottom was uncovered for a while, where they were doing some construction work?

A. On the western side of the rapids, immediately above the Horseshoe Falls, the Ontario Power Company uncovered quite an area of the bottom by their divertors; that is to say in the vicinity of and immediately below the first cascade in the rapids.

Q. Just go on and tell what the condition was at that time?

A. The area unwatered lay at the head of the rapids in a portion of the river of exceedingly high velocity and very broken currents. The water was exceedingly rough. The fall in that stretch of the river is about 55 feet in about a mile. It is exceedingly broken water, and very rapid.

Q. What effect would that condition have upon the bottom?

A. If the bottom was composed of soft limestone, as I believe it was—as I know it was—the rapid current and the turbulence of the water would cause large erosion on the limestone, probably following seams, and resulting in fissures and cracks of considerable magnitude. This was actually shown when the bottom was uncovered.

Q. Do you understand that that is the portion of the river referred to in Mr. Freeman's testimony, when he said there was a portion in the Niagara River uncovered for a while?

A. I am not familiar with Mr. Freeman's testimony.

Q. Is the condition at that place any indication of the nature of the bottom at the Bridge Section or the Open Section, which were measured by the Lake Survey?

A. So far as I can see it bears no relation whatsoever to the nature of the bottom at the International Bridge.

Q. Or the Open Section?

A. Or of the Open Section. The conditions are entirely different.

Q. Or of the Third or Split Section?

A. No. The conditions in all three cases are entirely different.

Q. What is the condition of the Niagara River at the gaging sections, with reference to turbulence?

A. At the International Bridge Section, there is a certain degree of turbulence around the bridge piers resulting from the placing of the piers in the current. It does not extend to any great distance either side of the piers. The turbulence on the bottom can be judged by the eye in spans 8 and 9. In those two spans, the water appears to be running absolutely smoothly and evenly over the bottom, with no eddying or boiling whatsoever. The indications of the current meters are that there is no eddying or boiling, or any great perturbation in the mid-spans, or near the edges outside of this certain narrow zone of disturbed water. At the Open Section, so far as I am able to judge, there is no turbulence whatsoever. The water appears to be running very smoothly and evenly. I am not familiar with the Split Section.

Q. Does the current meter give any indication of turbulence?

A. Not at the points at which I made observations; the registration is perfectly uniform and steady.

Q. I mean if there were any turbulence, would the current meter indicate it?

A. The current meter would indicate turbulence.

Q. How?

A. By an unsteady registration. We found that condition existing in the canal of the Hydraulic Power Company. The meter in that case would slow up, almost stop and then speed up; the registration was very irregular. In all of the large rivers in which we have made measurements, in which I personally have made measurements, I have found nothing of that kind whatsoever. The registration has been perfectly uniform and regular.

Q. That includes the St. Clair, the Niagara and the St. Lawrence Rivers?

A. That includes those three rivers.

Q. How is the Gorge Section of the St. Clair River as to turbulence?

A. There is no indication of turbulence at the Gorge Section, that I have ever been able to detect. There undobutedly

exists a slight perturbation close to the bottom, but it is very slight and is not extreme. The bottom of the Gorge Section is visible over the first 100 feet on the western side. The bottom consists of a rather fine, compacted gravel, and there is no sign of turbulence there whatsoever.

On the eastern side, the bottom is also visible. There it is smooth sand. There is no sign of any turbulence there. The registration of the meters at the bottom point in mid-stream where the depth is in the neighborhood of 65 feet was, as near as could be determined by ear as regular as it was in any other portion of the stream.

Q. How about the bottom of the St. Lawrence?

A. The bottom of the St. Lawrence is rougher. And if there is any turbulence in any of the rivers, it probably occurs there more than it does in the other stream. I have made no measurements near the bottom of the St. Lawrence; I could not say in that matter.

Q. Have you determined the time of the lag from the Buffalo gage to the Bridge Section where the measurements were made in the Niagara River?

A. I have.

Q. What is the time?

A. As I determined it in 1907, the time from the Buffalo gage to the Section, as I remember it, was eight minutes. It was in exact agreement with the time determined in the earlier observations; and that same time has been used in the reduction of all observations.

Q. What was that time, Mr. Moore?

A. I think it was about eight minutes. That is my recollection of it.

Q. How do you determine that?

A. By a comparison of the elevations on the gages with the automatic record. The stage line on each gage appears as a wavey line on the gage record. Peaks will appear on both gages, and the time between those peaks is scaled off the record. It is very determinate.

Q. What is the time from the Buffalo gage to the Open Section?

A. I should judge that to be about ten minutes. I have never made any measurements there.

Q. Have you read the testimony of Mr. Schoder and Mr. Turner in this case?

A. I have.

Q. Do you have in mind the tests that they say they made of the Haskell current meter?

A. I have, yes, sir.

Q. What is your opinion as to the value to be given to those tests as testified to by them, as a criticism of the Haskell current meter?

A. Judging by the photographs in evidence I should say that they were exceedingly lucky in obtaining an agreement between the weir and current meter anywhere near as good as they did. The sections as indicated on these photographs are sections which are absolutely unfitted for current meter measurements. Any person with experience in stream measurements with a current meter would never attempt to determine the flow of a stream in that condition, with a meter. According to Mr. Turner's testimony, the meter was vibrating both in a vertical and in a horizontal plane.

The measurements on the lower sections should have been in closer agreement to that determined by the weir, provided the error lay in the current meter. The fact that it does not would be an indication to me that the error lay in other elements than in the current meter.

The determination of the cross section under conditions of, that kind where as Mr. Turner testified the fluctuation of the water surface in the form of waves amounted to as much as .2 of a foot, would be exceedingly difficult, and might easily be in error by as much as 10 per cent. The determination of velocity co-efficients in a stream only 3 feet deep, is practically out of the question.

The indications as given by the weir, I do not believe show the actual, true flow. That is I would say I believe there is a possible error in the weir due to the method of calibration, and to the uncertainty of weir measurements in general. The observations, as I see them would tend to throw no discredit whatsoever on the meter measurements, but rather should add credit to the performance of the Haskell meter.

Q. Upon what in detail do you base your statement that you think there may be error in the weir measurements?

A. The weir was calibrated, as I understand it, by comparisons with another weir, by indirect comparisons with another weir, through a third weir, and the introducing of those two steps with an uncertainty in the calibration of the original weir would introduce further error into the determination of the weir used in determining the volume.

Q. Did you state whether or not there was any greater

precision in those tests further down stream where the water was in better condition than there was up near the baffles?

A. I stated that if the error lay in the current meter, those measurements down stream should show a more close agreement with the weir than those up stream. Judging by the photographs the water there was not in quite such a high state of perturbation. Mr. Schoder's testimony is to the effect that there is no appreciable law between the discrepancies shown in the distance from the baffles, and that appears to be the fact, in looking over the tests.

Q. I call your attention to vertical curves introduced by Mr. Turner of certain observations in the St. Mary's River. In your opinion do those curves and the deductions that he drew from them, have any effect upon the accuracy of the Haskell current meter or of the processes of river gaging?

A. The deductions drawn by Mr. Turner from those curves which he presents appear to me to be entirely unjustified by the observations. The curves which he has shown are plotted as absolute velocities, and there is no data to show that the discharge of the river when those curves were measured,—when each curve was measured, was the same; the indications are that it was not. The change in the flow of the river would of necessity change the absolute velocity, and the curves should show a divergence. The use of a second meter, which is customary in all the more recent work, and much of the previous work; in fact I believe it was only on one or two sections of the St. Mary's River that one meter only has been used, would have brought these curves together, undoubtedly.

If these curves should be reduced as percentage velocities instead of absolute velocities, it will be found that they do come together, by dividing each observation by the velocity at any one point on the curve, preferably the four-tenths and five-tenths depth.

The fact that the curves do diverge is merely the result of plotting velocities instead of percentage velocities, and it has no bearing on the accuracy of the work done on any of the other rivers or in the St. Mary's River at this particular station.

Q. From your study and work in the St. Clair River, do you have any opinion as to whether or not there has been a change in regimen in the St. Clair River?

A. I believe there have been minor changes in the regimen of the St. Clair River, since measurements were first

made there, but I do not believe that those changes have been of sufficient size to affect appreciably the volume of flow, or the increment as derived from the observations.

Q. Do you believe any large change of regimen occurred about 1890?

A. I can see no evidence of any large change of regimen in 1890 or in any of the years preceding, so far back as our records go.

Q. Have you been present and did you hear all of Mr. Ray's testimony?

A. I did.

Q. Did you hear his statement of the methods used by Mr. Williams in computing an increment from the observations?

A. I did.

Q. What is your opinion as to those methods?

A. I am unable to see how the stage preceding an observation by 24 or 36 hours or the stage following an observation can have any bearing whatsoever on the volume of flow at the time that the measurement was actually made. The fluctuation of the lake during that period, in my opinion, would be sufficient to render that method entirely erroneous. The result of the method would be to flatten the elevation at the lake, that is to reduce the elevation at the lake corresponding to the higher discharges, and to raise the elevation of the lake corresponding to the lower discharges, and hence to give an increment which would be larger than that shown by the observations.

The method of weighting the observations it seems to me is an entirely arbitrary method. I am unable to see any justifications for it. The weighting of observations tends to eliminate observations. Observations can be weighted to produce almost any result desired, if the weights are sufficient.

Q. What in your opinion is the relative value of an increment determined by a ratio of fluctuations between the lakes and an increment determined from a measurement of the river which empties the lake in question?

A. The determination of an increment from the relative fluctuations of the lakes is in general a rough check on that determined by actual observations in the outflow river, but in my opinion it is nothing more than a very rough check, and should not bet substitued for actual observations.

It is a deduction based on facts which are complicated

by various causes, and the result reached from a consideration of these facts cannot be compared in accuracy with that determined by actual observations.

Q. You have already testified as to a method of determining an increment at the Niagara River with reference to gages at the Whirlpool and Suspension Bridge; and in so doing you use a ratio of fluctuations, do you not?

A. Yes, sir.

Q. In what way are they different from the ratio of fluctuations from lake to lake?

A. The fluctuations of a gage in the Niagara River, or in the St. Lawrence River, are the result of the fluctuations in the elevation of the lake surface. The elevation of the lake surface determines the flow through the river, and the flow of the river determines the elevation of the gage on the river, on the lower pools.

In the case of the relative elevations of two of the lakes, the water surface elevation on one lake is only indirectly a function of the elevation on the other lake. The peak on Lake Erie is not caused by the peak on Lake Huron, because it occurs earlier in the year. It is probably the result of local supply.

In the case of a river, the local supply is infinitesimal in its effect on the gage relation. In one case the relation is well defined and definite, and in the other it is at best uncertain.

Q. In determining the ratio of fluctuation in the rivers themselves, that is only in the open season too isn't it?

A. Only the open season is used in determining the relationship between gages on the rivers, because ice effect would interfere with the law of relationship in the winter time.

Q. Now could you do the same thing, use the open seasons as between the lakes?

A. It would be possible to use only the open seasons between the lakes. There is a question as to whether you would gain very much from it on account of the large time interval probably existing. The knowledge of that is a theoretical consideration, which has been satisfactorily worked out, but it is still theoretical, and the relationship cannot in any way be anywhere near as intimate as it is in the case of a gage on a river in which there is no local storage, or anything of that kind.

Q. That is the reservoir effect of the lake?

A. Yes.

Q. When you say that it is a question whether you would gain much by taking the open season, do you mean gain much from taking the whole year as between the two lakes?

A. I mean that there would be a question in my mind at least as to whether the mean of the open season on two lakes expressed a true relationship between the lakes any better than a mean of yearly means.

Q. My point is whether you were comparing the open season with the whole year on the lakes, or whether you were comparing the open season on the lakes with the open season on a river?

A. I was comparing the open season on the lakes with the full year on the lakes.

Q. Having in mind the measurements of discharge of the three rivers, St. Clair, Niagara and St. Lawrence, do you see any inconsistencies in those measurements?

A. From what study I have given to the subject, I can see no large inconsistencies in the volume of flow of the three rivers.

Q. Now, Mr. Moore, calling your attention again to your work on the Sanitary District Canal near Chicago in December, 1913, just what did you do?

A. I measured the amount of water flowing through the Sanitary Canal at Lemont from the Stevens street bridge, between December 16 and December 22.

Q. How was the flow in the canal distributed?

Mr. Austrian: I move the answer be stricken out. It is a conclusion of the witness and not stating facts; upon the further ground that the answer is not responsive to the question.

Q. For how long a period of time were you engaged in that work, Mr. Moore?

A. We made observations on six days, usually from about nine o'clock in the morning until five in the afternoon. On one afternoon, the work was continued until seven o'clock; and on one night, the work was continuous throughout the night.

Q. About how many observations a day did you make?

A. The measurement of flow was practically continuous. The observations have been grouped covering periods of about 30 minutes, into 96 observations.

Q. With reference to the time of day, was there any difference in the flow?

A. The flow during the day time was decidely less than it was during the night hours.

Mr. Austrian: I move the answer be striken out as irresponsive, as stating a conclusion of the witness.

Q. How much difference was there, in a general way, Mr. Moore?

A. Roughly, about 1500 cubic feet per second.

Mr. Austrian: I move the answer be stricken out as stating the conclusion of the witness, and embodying a qualification not known to the law.

Mr. Hopkins: Q. Did you make any tests in that canal to determine the lag, or the time within which a crest would travel in the canal?

Mr. Austrian: I object to the form of the question as calling for the conclusion of the witness. I have no objection to the witness stating what he did; but asking whether or not be made any tests calls for a conclusion.

Mr. Hopkins: My question is did you make any, yes or no?

A. Yes.

Q. Just what did you do?

A. I read two gages, one at Lemont and one at Willow Springs, and compared the resulting elevations with respect to the time at which abrupt changes in the elevation took place.

Q. How far apart were those points?

A. About 7.8 miles.

Q. What was the result of your experiments?

A. The change in elevation was felt at Willow Springs about 30 minutes after it was felt at Lemont, due to changes below Lemont.

Mr. Austrian: Q. Mr. Witness, did you read both of those gages yourself?

A. I did not.

Mr. Austrian: I move that the testimony of the witness be stricken out as hearsay testimony.

Mr. Hopkins: Q. Would that same rate apply to other distances in that canal?

A. I believe it would.

Mr. Austrian: I move the answer be stricken out, as the witness has shown no knowledge on the subject, but gives his belief.

Mr. Hopkins: Q. Who was with you in that work?

A. Junior Engineer, A. B. Jones, of the Lake Survey and Recorder Harry Whittelem of the Lake Survey.

Q. Now in making these experiments as to the lag, that you have just mentioned, just what individuals took part in that, and what did each one of them do?

Mr. Austrian: I object to the form of the question, unless it is shown he was present and observed each one of the parties in question.

Mr. Hopkins: Q. Just who did the different things?

A. The gage at Willow Springs was read by Mr. Whittelem. The gage at Lemont was read by myself and by Mr. Jones.

Q. Were you in charge of this work?

A. I was.

Q. Was it done under your instruction and under your supervision?

A. It was.

Q. What caused these changes in elevation that you have spoken of?

A. The changes in the load on the power house at the lower end of the canal, and changes in the waste gates.

Q. Were the results of those observations put into a report by you and turned over to your superior officer?

A. They were.

Mr. Adcock: I move that be stricken out as immaterial.

Mr. Hopkins: Q. Is it a part of the records of the Lake Survey Office?

A. It is.

Mr. Adcock: I move that be stricken out as immaterial.

Mr. Hopkins: Q. Have you got that record?

A. Not here.

Q. Where is it?

A. It is in the files of the Lake Survey Office.

Q. Have you got a copy of that?

A. I have a portion of it.

Q. Have you the portion covering these observations with reference to lag?

A. I have.

Mr. Hopkins: Mr. Adcock, is there any objection on the gound that it is a copy rather than the original?

Mr. Adcock: No, if it is a complete copy.

Mr. Hopkins: Q. Have you a complete copy of the report as far as it pertains to these observations in reference to the lag?

A. I have.

Mr. Hopkins: Is there any objection on the ground that he is testifying to a copy rather than the original? If there is we will send down and get the original.

Mr. Adcock: No, not on that ground. I make the objection to the report going in. He can testify as to what was done in connection with that work.

Mr. Hopkins: Q. Will you refer now to the copy of the report that you have with reference to this particular matter, and tell us what results you obtained?

Mr. Austrian: I would like to ask the witness a question with reference to the report before he answers.

Mr. Hopkins: Go ahead.

Mr. Austrian: Q. Mr. Witness, the report that you refer to that was made, went to your superior officer after the completion of the work?

A. Yes, sir.

Q. That pertained to the Drainage Canal, between December 16 and 22, 1913?

A. Yes.

Q. And was all done pursuant to the direction of your superior officer that you referred to in your testimony in this connection?

A. It was.

Q. It was all a part of the same general direction and instruction referred to?

A. Yes.

Q. That is all the work you did pursuant to that direction and instruction?

A. Yes.

Q. And the entire report that you made to your superior officer was made shortly after you returned from that inspection and measurement and performance of the duty that you have just referred to?

A. Yes.

Q. And the entire report bears upon the whole observation, experiments, etc., taken in that connection, does it not?

A. No, it does not.

Q. Does it refer to anything other than the Drainage Canal of the Sanitary District of Chicago?

A. No.

Q. It all refers to the Sanitary District of Chicago, and was made to incorporate your observations, and the experiments that you have testified to?

A. Those were incorporated.

Q. What else was incorporated?

A. There were certain recommendations in regard to future—the best method of doing work in the future, provided we were called upon to do it.

Mr. Hopkins: Q. As appears in the report that you made in connection with those observations, which is a part of the record of the Lake Survey Office, what results did you obtain from the observations with respect to the lag from Willow Springs to Lemont, or vice versa, between those points?

A. Between 25 and 30 minutes.

Q. In your opinion will that same rate apply to the entire length of the Sanitary District Canal?

A. It will.

Q. Suppose the Sanitary District Canal is flowing 4,167 cubic feet of water in the direction of Lockport, and it is desired to open it to an extent so that it will take care of 10,000 cubic feet a second and flow it towards the town of Lockport, in what length of time can it be done?

A. The observations show that the change travels about a mile in four minutes. Applying this to the length of the canal would indicate that the effect would be felt at Lake Michigan in about 2 hours and 25 minutes. It is probable that the full effect might be a little behind this, but it is very certain that the time would not exceed three hours.

Q. You are familiar are you not with the canal itself?

A. I am.

Q. And the regulating gates down near Lockport?

A. I am.

Q. You had that in mind when you gave that opinion?

A. I did.

Q. Now in this work at Lemont, what was the area of the cross section which you obtained?

A. Approximately 4,000 square feet.

Q. And what instruments did you use in measuring the velocity?

A. I used two Haskell meters.

Q. Do you have there your blue prints showing the results you obtained, showing the volume of discharge?

A. I have, yes, sir.

Mr. Hopkins: I offer in evidence as Moore's Exhibits, 1, 2, 3, 4 and 5, the blue prints showing discharge measurements; the first four showing discharge measurements and the fifth showing the mean daily discharge.

(Whereupon blueprints offered in evidence were marked Moore's Exhibits 1, 2, 3, 4 and 5, February 5, 1914.)

MOORE'S EXHIBIT 1, FEB. 5, 1914.

Table 2.
In 4 Sheets.
Sheet 1.

U. S. LAKE SURVEY.
CHICAGO DRAINAGE CANAL.
Measurements of Flow by Index Meter.
LEMONT, ILL.

Elevations depend on
U. S. P. B. M. 90—591.560
U. S. P. B. M. 114—594.121
U. S. P. B. M. 120—592.133

Sherman Moore, Jun. Engr.
Jan. 1914

No.	Date 1913	Time	Meter	Index Velocity Ft. per Sec.	Mean Velocity Ft. per Sec.	Area Sq. Ft.	Flow C. F. S.	Water Surface Elevations			Fall to Lemont from		Wind	
								Lake Mich.	Willow Springs	Lemont	Lake	Willow Springs	Dir.	Vel.
1	Dec. 16	15:23-15:46	15-B	1.64	1.49	4015	5982	580.04		576.99	3.05		SW	8
2		15:47-16:18	15-B	1.71	1.55	4023	6236	580.04		577.04	3.00			
3		16:18-16:49	15-B	1.65	1.49	4024	5996	580.04		577.05	2.99			
4	Dec. 17	10:05-10:36	10-B	1.86	1.68	3885	6527	579.84		576.19	3.65			
5		10:36-10:58	10-B	1.84	1.67	3888	6493	579.84		576.21	3.63		W	20
6		11:37-12:07	10-B	1.82	1.65	3901	6437	579.74		576.29	3.45			
7		13:14-13:34	15-B	1.68	1.52	3964	6025	579.78		576.68	3.10		W	20
8		13:38-14:09	15-B	1.65	1.49	3974	5921	579.84		576.74	3.10			
9		14:09-14:46	15-B	1.70	1.54	3982	6132	579.95		576.79	3.16			
10		15:10-15:39	10-B	1.68	1.52	4013	6100	580.04		576.98	3.06		W	8
11		15:40-16:05	10-B	1.82	1.65	4023	6638	580.04		577.04	3.00			
12		16:07-16:27	10-B	1.68	1.52	4029	6124	580.04		577.08	2.96			
13		16:27-16:47	10-B	1.60	1.45	4032	5846	580.04		577.10	2.94			
14	Dec. 18	9:21- 9:43	10-B	2.06	1.87	3725	6966	580.19		575.20	4.99		N	6
15		9:50-10:13	10-B	1.97	1.78	3751	6677	580.24		575.36	4.88			
16		10:16-10:39	10-B	1.95	1.77	3772	6676	580.25		575.49	4.76			
17		10:47-11:08	10-B	1.89	1.71	3793	6486	580.24		575.62	4.62		NW	2
18		11:09-11:26	10-B	1.83	1.66	3812	6328	580.20	576.21	575.74	4.46	0.47		
19		11:37-12:01	10-B	1.75	1.58	3841	6069	580.15	576.32	575.92	4.23	0.40		
20		12:02-12:22	10-B	1.71	1.55	3867	5994	580.10	576.40	576.08	4.02	0.32		
21		13:31-13:56	15-B	1.65	1.49	3940	5871	580.20	576.90	576.53	3.67	0.37	N	4
22		13:57-14:21	15-B	1.71	1.55	3961	6140	580.26	576.98	576.66	3.60	0.32		
23		14:35-14:57	15-B	1.78	1.59	3976	6322	580.32	577.08	576.75	3.57	0.33		
24		14:58-15:20	15-B	1.70	1.54	3988	6142	580.38	577.17	576.83	3.55	0.34		

MOORE'S EXHIBIT 2, FEB. 5, 1914.

Table 2.
In 4 Sheets.
Sheet 2.

U. S. LAKE SURVEY.

CHICAGO DRAINAGE CANAL.

Measurements of Flow by Index Meter.

LEMONT, ILL.

Elevations depend on
U. S. P. B. M. 99—591.560
U. S. P. B. M. 114—594.121
U. S. P. B. M. 120—592.133

Sherman Moore, Jun. Engr.
Jan. 1914

No.	Date 1913	Time	Meter	Index Velocity Ft. per Sec.	Mean Velocity Ft. per Sec.	Area Sq. Ft.	Flow C. F. S.	Water Surface Elevations			Fall to Lemont from		Wind	
								Lake Mich.	Willow Springs	Lemont	Lake	Willow Springs	Dir.	Vel.
25	Dec. 18	15:23–15:45	15-B	1.67	1.51	4010	6055	580.40	577.24	576.96	3.44	0.28	N	4
26		15:46–16:05	15-B	1.64	1.49	4023	5994	580.44	577.33	577.04	3.40	0.29		
27		16:08–16:24	15-B	1.62	1.47	4028	5923	580.44	577.38	577.08	3.36	0.30		
28		16:24–16:45	15-B	1.62	1.47	4036	5933	580.44	577.46	577.12	3.32	0.34		
29	Dec. 19	9:58–10:23	10-B	1.79	1.62	3917	6346	579.98	576.79	576.39	3.59	0.40	SW	12
30		10:23–10:49	10-B	1.71	1.55	3938	6104	580.02	576.86	576.52	3.50	0.34		
31		10:50–11:27	10-B	1.78	1.61	3940	6343	580.04	576.96	576.53	3.51	0.43		
32		11:28–11:56	10-B	1.78	1.61	3943	6348	579.88	576.97	576.55	3.33	0.42		
33		13:06–13:36	15-B	1.53	1.39	4011	5575	579.78	577.27	576.97	2.81	0.30		
34		13:37–14:01	15-B	1.51	1.37	4016	5502	579.74	577.28	577.00	2.74	0.28		
35		14:07–14:30	15-B	1.54	1.39	4032	5604	579.78	577.37	577.10	2.68	0.27		
36		14:30–14:55	15-B	1.52	1.38	4037	5571	579.90	577.42	577.13	2.77	0.29		
37		15:01–15:30	15-B	1.48	1.34	4047	5423	579.94	577.46	577.19	2.75	0.27	SW	8
38		15:31–15:56	15-B	1.48	1.34	4062	5443	579.94	577.53	577.28	2.66	0.25		
39		15:58–16:21	15-B	1.50	1.36	4073	5539	579.94	577.60	577.35	2.59	0.25		
40		16:22–16:52	15-B	1.49	1.35	4076	5503	579.94	577.64	577.37	2.57	0.27		
41	Dec. 20	9:10– 9:33	10-B	1.88	1.70	3838	6525	580.16	576.37	575.90	4.26	0.47	SW	4
42		9:34–10:01	10-B	1.92	1.74	3854	6706	580.22	576.44	576.00	4.22	0.44		
43		10:14–10:39	10-B	1.89	1.71	3875	6626	580.31	576.57	576.13	4.18	0.44		
44		10:39–11:05	10-B	1.82	1.65	3886	6412	580.40	576.64	576.20	4.20	0.44		
45		11:14–11:47	15-B	2.04	1.85	3883	7184	580.44	576.73	576.18	4.26	0.55		
46		11:50–12:24	15-B	2.04	1.85	3886	7189	580.44	576.74	576.20	4.24	0.54		
47		13:44–14:16	10-B	1.37	1.24	4045	5016	580.44	577.25	577.18	3.26	0.07		
48		14:17–14:40	10-B	1.36	1.23	4066	5001	580.39	577.45	577.31	3.08	0.14		

MOORE'S EXHIBIT 3, FEB. 5, 1914.

Table 2. In 4 Sheets.
Sheet 3.

U. S. LAKE SURVEY.

CHICAGO DRAINAGE CANAL.

Measurements of Flow by Index Meter.

LEMONT, ILL.

Elevations depend on
U. S. P. B. M. 99—591.560
U. S. P. B. M. 114—594.121
U. S. P. B. M. 120—592.133

Sherman Moore, Jun. Engr.
Jan. 1914

No.	Date 1913	Time	Meter	Index Velocity Ft. per Sec.	Mean Velocity Ft. per Sec.	Area Sq. Ft.	Flow C. F. S.	Water Surface Elevations			Fall to Lemont from		Wind	
								Lake Mich.	Willow Springs	Lemont	Lake	Willow Springs	Dir.	Vel.
49	Dec. 20	14:40–15:07	10-B	1.32	1.20	4097	4916	580.34	577.62	577.50	2.84	0.12	N	6
50		15:07–15:34	10-B	1.30	1.18	4122	4864	580.34	577.77	577.65	2.69	0.12	N	6
51		15:35–15:59	10-B	1.49	1.35	4123	5566	580.34	577.91	577.66	2.68	0.25		
52		16:01–16:25	10-B	1.46	1.32	4131	5453	580.34	577.93	577.71	2.63	0.22	N	10
53		16:25–16:51	10-B	1.44	1.30	4156	5403		577.98	577.86		0.12		
54		16:55–17:00	10-B	1.88	1.70	4117	6999		578.06	577.62		0.44		
55		17:33–18:06	15-B	1.97	1.78	4071	7246		577.98	577.34		0.64	N	8
56		18:06–18:37	15-B	2.06	1.87	4065	7602		577.80	577.30		0.50		
57		18:37–19:13	15-B	2.03	1.84	4045	7443		577.75	577.18		0.57		
58		19:12–19:44	15-B	1.99	1.80	4031	7256		577.59	577.09		0.50		
59		19:44–20:15	15-B	2.03	1.84	4021	7399		577.56	577.03		0.53		
60		20:15–21:08	15-B	2.04	1.85	4005	7409		577.46	576.93		0.53		
61		21:28–21:58	10-B	2.15	1.95	3972	7745		577.30	576.73		0.57		
62		21:58–22:31	10-B	2.14	1.94	3961	7684		577.26	576.66		0.60		
63		22:31–23:04	10-B	2.11	1.91	3951	7546		577.20	576.60		0.60		
64		23:04–23:33	10-B	2.10	1.90	3941	7488		577.11	576.54		0.57		
65		23:33–24:04	10-B	2.08	1.88	3933	7394		577.05	576.49		0.56		
66	Dec. 21	0:04– 0:35	10-B	2.06	1.87	3928	7344		577.01	576.46		0.55		
67		0:35– 1:05	10-B	2.06	1.87	3919	7329		576.95	576.40		0.55		
68		3:04– 3:35	15-B	2.18	1.97	3890	7663		576.80	576.22		0.58	N	10
69		3:35– 4:06	15-B	2.14	1.94	3885	7537		576.79	576.19		0.60		
70		4:06– 4:37	15-B	2.17	1.97	3885	7653		576.77	576.19		0.58		
71		4:37– 5:08	15-B	2.12	1.92	3876	7442		576.74	576.14		0.60		
72		5:08– 5:39	15-B	2.14	1.94	3875	7518		576.73	576.13		0.60		

MOORE'S EXHIBIT 4, FEB. 5, 1914.

Table 2. In 4 Sheets.
Sheet 4.

U. S. LAKE SURVEY.
CHICAGO DRAINAGE CANAL.
Measurements of Flow by Index Meter.
LEMONT, ILL.

Elevations depend on
U. S. P. B. M. 90—591.560
U. S. P. B. M. 114—594.121
U. S. P. B. M. 120—592.133

Sherman Moore, Jun. Engr.
Jan. 1914

No.	Date 1913	Time	Meter	Index Velocity Ft. per Sec.	Mean Velocity Ft. per Sec.	Area Sq. Ft.	Flow C. F. S.	Water Surface Elevations			Fall to Lemont from		Wind	
								Lake Mich.	Willow Springs	Lemont	Lake	Willow Springs	Dir.	Vel.
73	Dec. 21	5:39- 6:10	15-B	2.13	1.93	3872	7473		576.72	576.11		0.61		0
74		6:10- 6:42	15-B	2.13	1.93	3868	7465		576.68	576.09		0.59		
75		6:42- 7:03	15-B	2.13	1.92	3867	7425		576.68	576.08		0.60		
76		7:03- 7:14	15-B	1.70	1.54	3928	6049		576.70	576.46		0.24		
77		7:14- 7:24	15-B	1.48	1.34	3980	5333		576.70	576.78		—0.08		
78		7:24- 7:46	15-B	1.18	1.07	4024	4306		576.92	577.05		—0.13		
79	Dec. 22	9:46-10:12	15-B	1.86	1.68	3961	6654	580.43	577.09	576.66	3.77	0.43		0
80		10:13-10:39	15-B	1.95	1.77	3953	6997	580.45	577.12	576.61	3.84	0.51		
81		10:39-11:05	15-B	1.95	1.77	3951	6993	580.44	577.12	576.60	3.84	0.52		
82		11:07-11:31	15-B	1.98	1.79	3953	7076	580.42	577.13	576.61	3.81	0.52		
83		11:31-11:58	15-B	1.98	1.79	3953	7076	580.38	577.12	576.61	3.77	0.51		
84		13:03-13:24	15-B	1.56	1.41	4045	5703	580.20	577.45	577.18	3.02	0.27	S	4
85		13:25-13:43	15-B	1.58	1.43	4040	5777	580.17	577.48	577.15	3.02	0.33		
86		13:47-14:08	15-B	1.62	1.47	4050	5954	580.14	577.53	577.21	2.93	0.32		
87		14:09-14:40	15-B	1.66	1.50	4060	6090	580.14	577.59	577.27	2.87	0.32		
88		14:44-15:03	15-B	1.64	1.49	4065	6057	580.14	577.62	577.30	2.84	0.32	S	4
89		15:04-15:37	15-B	1.57	1.42	4073	5784	580.14	577.66	577.35	2.79	0.31		
90		15:50-16:16	10-B	1.60	1.45	4091	5932	580.14	577.75	577.46	2.68	0.29		
91		16:17-16:47	10-B	1.55	1.40	4102	5743	580.14	577.80	577.53	2.61	0.27		
92		16:49-17:03	10-B	1.53	1.39	4102	5702	580.14	577.86	577.53	2.61	0.33	NNE	8
93		17:03-17:16	10-B	1.73	1.57	4100	6537		577.87	577.52		0.35		
94		17:17-17:40	10-B	2.29	2.07	4010	8301		577.74	576.96		0.78		
95		17:40-18:21	10-B	2.38	2.16	3969	8573		577.45	576.71		0.74		
96		18:21-18:53	10-B	2.28	2.06	3966	8170		577.34	576.69		0.65		

MOORE'S EXHIBIT 5 FEB. 5, 1914

U S LAKE SURVEY

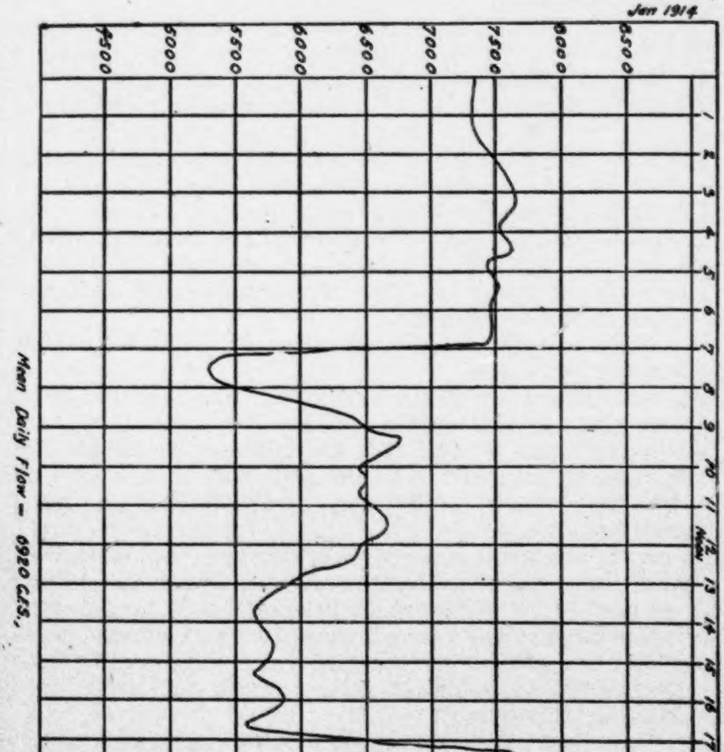
Plate 4

CHICAGO DRAINAGE CANAL

Mean 24 Hour Curve of Flow

Lemont, Ill.

SHERMAN MOORE, Jun. Engr
Jan 1914



Mr. Hopkins: Q. Mr. Moore, what do those exhibits show?

A. Exhibits 1, 2, 3, 4 are a tabulation of the measurements made in the Drainage Canal at Lemont in December. The first column is the number of the observation.

The second column is the date on which the measurements were made.

The third column shows the time of day on which the measurements were made.

The fourth column shows the number of the current meter used.

The fifth column gives the index velocity in feet per second.

The sixth column gives the mean velocity in feet per second.

The seventh column gives the area of the section in square feet.

The eighth gives the flow in cubic feet per second.

The ninth column is the elevation of Lake Michigan at Chicago.

The tenth column is the elevation of the water surface of the canal at Willow Springs.

The eleventh column is the elevation of the water surface of the canal at Lemont.

The twelfth column is the fall in the water surface from Lake Michigan to Lemont.

The next column is the fall in the water surface from Willow Springs to Lemont. And the last two columns give the direction and velocity of the wind at the time of the measurements at Lemont.

Exhibit 5, is a graphical representation of the flow through the canal during the week that measurements were made there, with respect to its distribution through the 24 hours.

Q. Mr. Moore, will you tell us in inches what the lowering effect upon Lakes Michigan and Huron, Erie and Ontario, as you compute it, would be of a diversion of 10,000 cubic feet of water at Chicago?

A. The effect of the diversion of 10,000 cubic feet at Chicago would be to lower the surface of Lakes Huron and Michigan about 5 1/5 inches; the surface of Lake Erie about 5½ inches, and the surface of Ontario about 5 inches.

Q. How about Lake St. Clair?

A. Lake St. Clair would be lowered about 5¼ inches.

Q. How about the St. Clair and the Detroit Rivers?

A. They would be lowered about the same amount.

Q. Would it have any effect in the channel up towards the St. Mary River?

A. It would have an effect in the channel as far as the locks.

Q. And to what extent?

A. The lowering in the lower reaches of the St. Marys River would be the same as it on Lake Huron, 5½ inches. The lowering would diminish slightly as you went up the river.

Q. What do you think it would be at the locks approximately?

A. Probably in excess of 4 inches.

Q. For any other diversion at Chicago, from 1 to 14,000 cubic feet, would the lowering in the places mentioned be in the same direct proportion?

A. It would be directly proportionate.

Mr. Hopkins: That is all.

Cross-examination reserved.

SHERMAN MOORE, recalled for further examination, testified as follows:

Cross-Examination by Mr. Adcock.

Q. You received the degree of Civil Engineer in the University of Wisconsin in 1907?

A. Yes, sir.

Q. And you were graduated, I presume, from the Academic Department in 1902?

A. Graduated from the Civil Engineering Department in 1902, with the degree of Bachelor of Science in Civil Engineering. I received the master's degree of civil engineer in 1907.

Q. And from 1902 on, you were connected with the Lake Survey?

A. I have been connected with the Lake Survey since 1902.

Q. That is immediately after you graduated from college, you came with the Lake Survey?

A. I did.

Q. And the first work, first measurement of streams you did was in 1907 and '08 on the Niagara River. Is that correct?

A. That is right.

Q. Prior to that time you had been doing what? What were your duties?

A. In 1902, I had charge of the triangulation on the St.

Lawrence River, in connection with a resurvey of the river; and also did a large amount of topographical surveying.

In 1903 and 1904, and part of 1905, I was connected with the primary triangulation from the Straits of Mackinaw to Lake Erie, and did all of the reconnaissance work and station building.

In the latter part of 1905, I made topographical surveys including some triangulation, on Sandusky Bay and the Portage River. And in 1906, I assisted on the resurvey of the Niagara River, having charge of the triangulation the redetermination of the crest line of the falls and soundings above the rapids.

Q. In your triangulation work, did you have charge of the party?

A. I did not have charge, technically.

Q. Who was your superior, immediate superior?

A. On the primary triangulation, Mr. H. F. Johnson.

Q. And in 1907 and 1908, you assisted in the gaging on the Niagara River?

A. In 1907, and 1908, I had charge of all of the hydraulic work, the investigations on Niagara Falls.

Q. And that consisted partly in gaging the Niagara River?

A. In part.

Q. At the International Bridge Section?

A. In part.

Q. And the Open Section?

A. No.

A. Not at the Open Section.

Q. Not at the Open Section?

Q. That was the first work you did in connection with stream gaging?

A. The first work I did in connection with stream gaging was to measure the flow through the canal of the Hydraulic Power Company.

Q. That was in the same year?

A. That was in the same year.

Q. And you had charge of that work as well as the work on the Niagara at the bridge section?

A. I did.

Q. Was anyone else connected with you in that work?

A. Mr. Richmond was my first assistant.

Q. What was your title then?

A. Junior Engineer.

Q. What was the next work you did in stream gaging?

A. May I ask after what?

Q. The next?

A. After what?

Q. What we have been talking about. The work at the Niagara River, that is the last thing we have talked about.

A. The last thing we talked about was something else.

Q. No, it was not. It was the Niagara River, Bridge Section?

A. In the fall of 1908 I made measurements on the St. Clair River.

Q. Where?

A. Section Gorge and Section Dry Dock.

Q. And then what was your next work in stream gaging?

A. In 1909, I measured the flow in the canal of the Niagara Falls Power Company, determining the efficiencies of the turbines and deriving the limitations under which they operated.

Q. You had charge of that work?

A. I had charge of that work.

Q. What was the next work you did in connection with stream gaging?

A. That same summer, I measured the flow through the canal of the Hydraulic Power Company and determined the maximum output for their plant under the limitation of water prescribed by the Secretary of War. In the fall of that year I continued measurements—

Q. On the same river?

A. I continued measurements on the St. Clair River. I neglected to state that in 1908, I made measurements on the St. Lawrence River.

Q. Instead of the St. Clair?

A. In addition.

Q. And the last work you mentioned on the St. Clair River, where was that done?

A. In both Sections Gorge and Dry Dock.

Q. What was the next work you did in connection with stream gaging?

A. In the spring of 1910, I resumed measurements on the St. Clair River at both Section Gorge and Section Dry Dock, and established the hydraulic sections in the Delta, making some measurements on them. I had charge of the work in 1910, until the first of July, when I was transferred to other work.

Q. Since that time, have you done any stream gaging?

A. In December of 1911, I made measurements in the canal of the Hydraulic Power Company and determined the maxi-

mum output under the conditions under which they were then operating.

Q. That is at Niagara?

A. The Hydraulic Power Company at Niagara Falls.

In December of 1913, I measured the discharge of the Drainage Canal at Lemont.

Q. And in all this work of stream gaging, you had charge of the work, as I understand it, since 1907, when you commenced on the Niagara River?

A. In all of the stream gaging that I ever did, I had charge of the work.

Q. What is your title now?

A. Junior Engineer.

Q. That is the Lake Survey?

A. United States Junior Engineer.

Q. From whom did you receive instructions as to the method of gaging streams?

A. My knowledge of the methods which I employed in gaging streams has been derived from a study of the method employed by Mr. Shenehon on the Niagara and St. Lawrence Rivers, by Mr. Sabin on the St. Clair River; by the Geological Survey, and various other sources.

Q. Did you receive any instructions, while you were obtaining your master's degree, and B. S. degree?

A. Very slight instruction.

Q. That is while in college, or in your work at Wisconsin?

A. Very slight instruction.

Q. What instruction did you receive or what studies did you make at that time?

A. I don't believe that I can remember very definitely what was done. I remember of rating the Haskell meter, rating the Price meter and measuring in a rather crude way the flow of a small stream there. The instruction was about that given by most engineering schools, which is very slight.

Q. What did you learn from the study of the Geological Survey work?

A. I have employed their methods to some extent in certain work in connection with work in power canals. It has influenced to some extent the method which I have developed.

There is one matter that I omitted in my answer to that question in regard to the measurements I had made. I neglected to state that in 1909 I measured the flow of the St. Marys River from the International Bridge at the Soo, and the flow through the three power canals there.

Q. Do you remember the name of the stream in Wiscon-

sin which you measured before you entered the Lake Survey?

A. I believe it is called the Yahara River.

Q. That is the only work that you had done in that connection?

A. That is the only work that I did there.

Q. Or in measuring streams, before you entered the Government service?

A. Or measuring streams before I entered the Government service.

Q. What was the size of that stream? Do you remember?

A. I don't remember exactly. It was somewhere in the neighborhood of 40 or 50 feet wide and 1 to 3 feet deep, I believe.

Q. In your stream gaging, you have used the Haskell meter?

A. In the larger part of my work, I have used the Haskell meter, because I believe it the only accurate meter on the market to-day. I have also used the Price meter, under certain conditions.

Mr. Adcock: I move to strike out that portion of the answer which states: "Because I believe it to be the only accurate meter in use to-day." It is not responsive to the question.

Q. Now, you say in fitting yourself to measure streams, you studied the work of Mr. Shenehon and Mr. Sabin?

A. I did.

Q. Did you study the work of anyone else outside of them, in connection with the Geological Survey that you mentioned?

A. I do not recall any names. I am familiar with a large part of the work done by the Geological Survey.

Q. I asked you outside of the Geological Survey?

A. I misunderstood your question.

Mr. Adcock: If you will follow the questions, we may get along better, Mr. Witness.

Q. What type of Haskell meter did you use in connection with your work in stream gaging?

A. Principally the B type, although I used the A type to some extent.

Q. To what extent?

A. I used an A meter in the measurements from the International Bridge at Buffalo, and in the first two seasons work on the St. Clair River; I believe it was the first two seasons; in the first season anyway. I am not certain about the second.

Q. And since that time, you have not used the A meter?
A. I have not used the A meter.
Q. What tests did you make of the Haskell meter before you entered upon your work of gaging the Niagara River at the bridge section?
A. I don't understand what you mean.
Q. How did you happen to use that meter?
A. I used that meter because that meter was furnished me by the Lake Survey.
Q. Did you make any soundings in the St. Clair River at the Gorge Section?
A. I have.
Q. You used the same apparatus that Mr. Richmond described that he used in his work?
A. Substantially the same.
Q. In what particular was it different?
A. Simply in minor particulars, which I do not recall at the present time, unimportant particulars.
Q. Did you use the same weight?
A. Used the same weight.
Q. Same size?
A. Same size.
Q. Did you observe the inclination of the sounding wire at the Gorge Section?
A. I did.
Q. Did you do any soundings in the Niagara River?
A. I made soundings in the Niagara River.
Q. Where?
A. At the International Bridge and spans 1, 2, 3 and 4 on the American side.
Q. How frequently were the soundings made?
A. I don't remember.
Q. Well, was it two feet apart?
A. I don't remember.
Q. Have you any notes with reference to that?
A. There is a record in the office.
Q. Could you get hold of those notes and refresh your recollection?
A. I can in about an hour's time, probably.
Mr. Adcock: I presume that you will have to get them, then, and have them here.

Recess to 2:15 P. M.

February 19, 1914, 2:15 P. M.

SHERMAN MOORE, resumed the stand and testified further, as follows:

Mr. Adcock: Q. How frequently as an average were soundings made on the Bridge Section?

A. The soundings at the International Bridge Section were on the average about 20 feet apart in the resounding. No attempt was made to determine definitely the new cross section. The idea was simply to determine whether there had been any scour, and a few soundings were taken at intervals of about 20 feet across each span.

Q. In what panels were those?

A. Panels 1, 2, 3, and 4.

Q. What was the greatest depth?

A. The greatest depth was about 48½ feet.

Q. What stage was that referred to?

A. 567.24 at the section gage.

Q. In what panel was this deepest point, 48½ feet?

A. The middle panel in span 4.

Q. About the middle of the panel of 4?

A. It occurred in the middle panel in span 4.

Q. What is the number of the panel?

A. The index point I believe was known as 4 6/12ths.

Q. The index point? Read the question.

Mr. Hopkins: What does that 4 6/12ths mean?

A. It means that the index point for that panel was in the fourth span and 6/12ths of the distance across the span.

Mr. Adcock: Q. But you did not number the panels?

A. No.

Q. What was the inclination of the sounding wire?

A. That I could not say at the present time. I have not found that notebook yet.

Q. What have you got?

A. I think I can answer what you want to know in regard to the St. Lawrence River.

Q. You are still searching for your other records, are you?

A. Yes.

Q. You can take that up later then? Did you do any soundings in the St. Lawrence River?

A. I made soundings on the St. Lawrence River from stations 4 to 14, inclusive.

Q. And there were 17 in all, were there?

A. There were 17 in all, I believe.
Q. On what section?
A. Section Three point.
Q. Same place that Mr. Shenehon sounded in his early work?
A. Practically the same.
Q. When you say "practically," what do you mean?
A. There was some slight uncertainty in reproducing the section. Some of the old monuments were not definitely found. The soundings were probably within two or three feet of the old section.
Q. What was the depth, maximum depth?
A. The greatest sounding when reduced was about 56 feet.
Q. That was referred to what stage?
A. 225.88 by Mr. Shenehon's level reduction. I believe that is about .06 of a foot different from the 1903 reduction.
Q. What was the weight used?
A. Cast iron sounding weight of 140 pounds approximately.
Q. What was the inclination of the sounding wire at that point?
A. 13 degrees.
Q. What was the mean velocity in that vertical, or the index velocity if you have it, either one?
A. I haven't the mean velocity, but it is about 5¼ feet per second.
Q. That is the mean?
A. That is somewhere in the neighborhood of the mean.
Q. Have you the index velocity?
A. That is the index velocity.
Q. What was the inclination of the meter cable at that vertical?
A. About 30 degrees.
Q. Is that the .9 depth or bottom?
A. That is .4 depth.
Q. What was it at the .9 depth?
A. I made no observations there.
Q. You did not do any co-efficient work there?
A. No.
Q. What was the meter used?
A. The meters used were type B, Haskell meters, with 40-pound leads.
Q. That was the same weight that was used by Mr. Richmond at the Gorge Section at the St. Clair?
A. It was not. Mr. Richmond used 140 pound weights.
Q. And the same weight that you used on the Niagara?

A. It was the same weight.

Q. Which was the 140 or the 40 pound?

A. 40 pound.

Q. Have you a vertical there where you made soundings, and the deflection of the sounding wire was approximately 10 degrees?

A. (No response.)

Q. Did you use the same size sounding wire on the Niagara and St. Lawrence that was used by Mr. Richmond, that he described yesterday, in connection with the Gorge Section?

A. I believe so.

Q. And similar to the one that he used in the Split Section?

A. I believe so.

Q. Do you know whether Mr. Shennehon used the same size wire, sounding wire?

A. I don't know that he used the same size wire, but I believe that he did, wire that was closely comparable.

Q. That is your best recollection?

A. Yes.

Q. (Question read as follows: "Have you a vertical there where you made soundings and the deflection of the sounding wire was approximately 10 degrees.")

A. That seems to be the case on vertical 8.

Q. What was the depth there?

A. 50 feet.

Q. What was the deflection of the meter cable at the .4 depth?

A. Approximately 28 degrees.

Q. What was the index velocity?

A. About 5½ feet per second.

Q. That was approximately the same as the other vertical that you just mentioned?

A. Not materially different.

Q. How nearly correct is that index velocity that you gave?

A. That index velocity that I gave is the velocity to the nearest half foot which I happened to pick off of a certain discharge measurement.

Q. Can you give any more accurate statement as to the index velocity at that point?

A. I can average these 30 discharges, or I can give you the actual velocity when the angle was 28 degrees.

Q. All right, give us that?

A. I will have to get the rating tables to do that.

Q. What was the size of the meter cables used in these different places?

A. The size of the meter cables vary. At certain places it was one size and at other places it was another.

Q. Did you use the same size on all the meters on the St. Lawrence gagings?

A. I could not say. There is no record kept of the size of the cable.

Q. How about the Niagara gagings?

A. There was no record kept.

Q. Or the St. Clair gagings?

A. There has never been a record kept of the size of the cables.

Q. Did you use a different sized cable on the A meter from what you used on the B meter?

A. I am unable to say. No record was kept. There was no intention to use a larger cable on the A meter than there was on the B meter.

Q. You had charge of the St. Lawrence gagings and the Niagara gagings, did you not?

A. I did.

Q. Have you any recollection about that?

A. My recollection is that there were two sizes of cables in use. They would be used indiscriminately with the meters. The meters would be used first on one side and then on the other. The size of the cable would vary every time a new core wire was put in, and the matter seemed to have so exceedingly little importance that no record was ever made of it.

Q. Did you ever make any investigations as to that question, as to the importance of the meter wire, size of it?

A. No, I never did.

Q. You don't consider then that the size of the meter cable would have anything to do with the deflection of the meter cable when the meter was submerged?

A. The size of the meter cable probably would influence to some extent the angle of deflection at the surface, but the influence would not be sufficient to change the correction to the depth by an appreciable quantity.

Q. And to what extent would it be influenced at the surface?

A. To a very much less extent.

Q. How many discharge measurements did you make on the St. Lawrence?

A. About 25 measurements.

Q. Take vertical 8, for instance, did you read the deflection of the meter wire, each time you took a velocity observation?

A. I did not.

Q. How many times did you?

A. I could not say. I find the record here of one or two times but they were not always recorded.

Q. How many records have you of meter wire deflections at that vertical?

A. I only find three such.

Q. You find three?

A. I find three.

Q. Give the deflections that you find there, and the index velocities corresponding to the deflection?

A. I believe there are more than three here. I find here five observations of the deflection of the meter cable on Station 8.

Q. Have you the index velocities corresponding?

A. With an index velocity of 5.40, there was an observed angle of 28 degrees. With an index velocity of 5.55, there was a deflection angle of 30 degrees. With an index velocity of 5.54, there was a deflection of 30 degrees. With a velocity of 5.50, there was a deflection of 30 degrees. With a velocity of 5.63, there was a deflection of 27 degrees.

Q. All with the B meter, were they?

A. They were all B meters. They were not the same meters.

Q. The same Haskell meter, B Haskell meter?

A. Same design of meter.

Q. And the same weights on each meter?

A. Same weight on each meter.

Q. What was the number of the vertical where that was 56 feet?

A. Vertical 9.

Q. Referring to vertical 9, give us the same information as to that?

A. I find four observations of the deflection angle at station 9. Wtih a velocity of 5.64, the deflection was 32 degrees. With a velocity of 5.76, the deflection was 31 degrees. With a velocity of 5.60, the deflection was 31 degrees. With a velocity of 5.85, the deflection was 32 degrees.

Q. Have you another vertical there besides the one you

have mentioned, where the deflection of the sounding wire was 10 degrees?

A. I see no other vertical at which the deflection was exactly 10 degrees.

Q. How near?

A. There is one here 9 degrees, vertical 7.

Q. Give us the same information as to the deflection of the meter wire, and the index velocity, on vertical 7; and also the depth?

A. I find five observations of the deflection of the meter cable on station 7. With a velocity of 5.48, the deflection was 25 degrees. With a velocity of 5.57, the deflection was 26 degrees. With a velocity of 5.64, the deflection was 27 degrees. With a velocity of 5.79, the deflection was 27 degrees. With a velocity of 5.60, the deflection was 26 degrees.

Q. What was the depth?

A. The depth at station 7, reduced to stage of 525.88, by the section gage was 43 feet.

Q. How frequently did you make soundings on the St. Lawrence River in this section?

A. Every 10 feet.

Q. What evidence of boulders did you find on the St. Lawrence Section, Three Point?

A. The soundings showed no evidence of any large boulders. There are occasional differences in the soundings of one and two feet in which the intermediate sounding is less than those on either side, which may indicate boulders.

Q. What evidence did you have as to the condition of the bottom of the Niagara River, as to whether there were boulders or other irregularities at the bottom of the Niagara River?

A. The sounding weight was moved about a foot on either side of the exact point; in some cases more than that, without showing any sudden increase or decrease in the depth. On the Canadian side of the river, the bottom is visible and appears to be smooth.

Q. On the Niagara River, you sounded about every 20 feet?

A. Soundings were made about every 20 feet.

Q. Did you make any soundings above or below the section?

A. I did not.

Q. The soundings that you made were as near as you could make them right on the section, were they not?

A. I will modify that statement slightly. Soundings were made below the section in spans 3 and 4.

Q. How far below?

A. I should judge about ten feet.

Q. How often?

A. Every 20 feet.

Q. You stated that there was no turbulence of the water on the Niagara River?

A. There is turbulence around the bridge piers; a short distance away from the bridge piers the water is running smoothly and evenly.

Q. How was it at the bottom?

A. On the western side where the bottom was visible, the current appeared to be very smooth and regular.

Q. How deep was it there?

A. The depth where the bottom was visible ranged from zero up to about 10 to 12 feet.

Q. How far did that extend?

A. My impression is it extended part way into the second span from the Canadian side. I don't remember exactly how far it extended.

Q. At the depth of ten feet that you speak of, how would the turbulence appear at the bottom to the eye, if there were any turbulence?

A. I believe that if the current was in a perturbed condition that particles of sand and silt which were being carried along would make the turbulence visible.

Q. I understood you to say it was a rock bottom?

A. It is a rock bottom. There was more or less sediment at times going down the river.

Q. If there were very much sediment, you could not see that deep?

A. There were times when it was impossible to see the bottom on account of the sediment.

Q. Then it must have been turbulent at that time?

A. Not necessarily.

Q. Have you your data here with reference to the Niagara, that you were going to try and get?

A. Yes, I have. I think I have what you desire.

Q. You mentioned a vertical where the depth of the water was 48½ feet. What was the inclination of the sounding wire at that point?

A. The deflection of the sounding wire was 13 degrees.

Q. That was in span 4, was it not?

A. That was in span 4.

Q. What was the inclination of the meter cable and the index velocity, that you have records of?

A. At that point?

Q. At that point, yes, at that vertical.

A. I find no record in the discharge book of any deflections of the meter cable. They were apparently not recorded.

Q. You have no records of any deflection at any vertical?

A. I have no record of any deflections at any vertical.

Q. Were those deflections read?

A. I believe they were.

Q. What year did you do your work on the St. Lawrence?

A. On the St. Lawrence in 1908.

Q. And this work on the Niagara was done in 1907?

A. 1907, and 1908.

Q. Well, what is your recollection about that? You say you think they were. Do you have any recollection as to whether they were read or not?

A. According to my recollection they were. I would not want to say that they were, and yet as I remember it they were.

Q. Whose duty was it to take those observations?

A. The deflection might be read by any member of the party. They were not read at every measurement, by any means, but I believe they were read occasionally.

Q. There were 118 discharge measurements?

A. 126.

Q. 126 discharge measurements made by you at that time in the Niagara?

A. Yes.

Q. And the only co-efficient work that you did was on the St. Clair River, wasn't it?

A. That is the only large river in which I have done co-efficient work.

Q. And Mr. Richmond was in your party was he?

A. He was.

Q. You testified before in this case on May 25, 1909, did you not?

A. I believe that was the date.

Q. You then described the method and apparatus used by you in making soundings on the Niagara River, did you not?

A. I believe I did.

Q. I call your attention to your testimony, as it appears

on page 413 of the record, in answer to the question: "How did you make those soundings? Will you give us the method Mr. Moore?" I will ask you to read your answer to that question, and I will then ask you to state if that correctly states the method used?

A. (Reading) "The soundings were made by means of a cast-iron weight, which was of the projectile type, a sphere drawn out into cones on each end, with a wooden tail to hold the nose of the weight in the line of the current. The weight used there was 135 pounds. It was suspended with steel piano wire, a little less than 1/10th of an inch in diameter. This wire was carried on the drum of a reel which rested on the chord of the bridge. The circumference of the drum was exactly three feet, and the depth was determined by the revolutions and partial revolutions of the drum. In spans 3 and 4, the velocity of the current was so great that in order to bring the weight to the bottom in the plane of the section it was necessary to cause the wire to enter the water at about four feet above the line of the section. This was done by a heavy weight which carried a hook which engaged the sounding wire. The auxiliary weight was suspended from the downstream chord of the bridge and a guy line was run to the upstream chord of the bridge, so that the weight and the sounding wire could be pulled back upstream any desired distance. The angle of inclination of the wire did not exceed 18 degrees; it was usually much less. The weight was lowered to the water surface, and the readings of the circumference of the drum was taken with the weight just touching the water surface. Then it was lowered to the bottom and a second reading on the drum was taken. The weight was then raised just clear of the bottom, and the angle which the wire made with the vertical was measured. The difference between the two readings, corrected for the inclination of the wire was the sounding; gave the depth of the water. It was referred to a fixed plane by the readings of a gage on the shore."

The statement of the method used is correct.

Q. Is that the same weight used on the St. Lawrence soundings?

A. Same type of weight.

Q. These sounding weights were made from the same mold, were they?

A. Yes.

Q. And they were as near the same size as could be obtained?

A. Yes.

Q. How accurately in your opinion was the depth of the Niagara obtained at the point where soundings were taken?

A. I believe that individual soundings were correct as a rule within seven or eight-tenths of a foot.

Q. What would be the per cent. of error that you speak of?

A. In 40 feet of water, about 2 per cent.

Q. Were the soundings repeated in the same position?

A. They were.

Q. How many times?

A. In the soundings that I made from the International Bridge, every alternate sounding was determined by two observers independently. I don't know how often the original soundings were repeated but it has been quite customary to make soundings more than once.

Q. What percentage of accuracy does that give to the soundings at any one point?

A. I stated that one sounding might be in error by about two per cent.; two soundings, the error of the depth determined by two soundings, would be approximately one-half of that.

Q. That would be about 1 per cent.?

A. Somewhere in that neighborhood. Individual soundings might show greater discrepancy than I was speaking of.

Q. Greater than two per cent.?

A. Greater than two per cent.

Q. How many soundings were taken then at one point?

A. Didn't I just answer that question?

Q. I don't think so. You stated that every alternate sounding was—

Mr. Hopkins: He said he didn't know how many, in some cases more than one.

Mr. Adcock: Q. Were made by two independent parties. Now, are we to understand from that that there was some place or were some places where there was only one sounding made?

A. In some places.

Q. And in others there were two soundings made?

A. In my work on the Niagara River, at some points there was one sounding and at each alternate point there were two soundings.

Q. And on the St. Lawrence River?

A. I believe that on the St. Lawrence River there was

but one sounding made on a point, with the exception of a portion of the area which was sounded the second time.

Q. There was some portion of the area sounded the second time?

A. I believe so.

Q. What was the reason for that?

A. The reason for the second sounding was to get a check on the work.

Q. And in the St. Clair, what were the conditions?

A. Section Gorge was sounded either three or four times, I don't remember which.

Q. What was the reason that you sounded so many times on the Gorge as compared with the number on the St. Lawrence and the Niagara?

A. There appeared to be some slight uncertainty in regard to the exact location of the sounding as determined by the transit angles, and as the bottom of the river on the west side is exceedingly steep, the soundings were repeated until we were certain we had positive results.

Q. Were they repeated all the way across the number of times which you mentioned?

A. No.

Q. How far across?

A. They were taken all the way across twice, and more than half way across I think four times.

Q. In lowering the weight by the method which you spoke of, if the drum made ten revolutions before the weight struck bottom and you were in still water, what depth would that indicate?

A. Approximately 30 feet.

Q. And if it were in water with a mean velocity of 6 feet per second, what would be the depth?

A. I don't know what the depth would be without the angle of inclination of the wire.

Q. Knowing the angle of the inclination of the wire, how would you determine the depth?

A. The problem of determining the curve taken by the wire in the current is a mathematical problem which is capable of solution on several assumptions, all of which give practically the same results. Those computations have been made for various deflection angles, and tables computed showing the correction to be applied to the amount of wire reeled off the drum.

Q. Did you use the table in the making of that correction,

which is shown as table number 1, page 5330, report of Chief of Engineers for the year 1898?

A. I did not.

Q. For 1900 rather?

A. For the work on the Niagara River, and for the sounding on the St. Clair and St. Lawrence Rivers, I did use table 1, on page 5330 of the report of Chief of Engineers for 1900.

Q. How was that table computed?

A. The table is computed by considering the pressure of the water against the wire over each tenth of the depth as determined by the velocity of the water, the variation in velocity being determined by typical vertical velocity curve.

Q. Was the velocity considered uniform from top to bottom in the computation of this table?

A. It was not. It was considered as varying, as shown by typical velocity curves.

Q. How near 30 feet would that wire be unwound to the extent of ten revolutions?

A. In still water, it would be 30 feet corrected for the diameter of the reel.

Q. If the circumference of the reel were exactly three feet as you stated?

A. If the circumference of the reel were exactly three feet, in still water there would be no correction.

Q. If you wind a wire .1 of an inch in diameter around a drum having a circumference of exactly three feet, and unwind the wire through ten complete revolutions of the drum, what length of the wire have you released?

A. It depends on the size of the wire.

Q. I have stated, one-tenth of an inch in diameter?

A. I would have to make a computation of that.

Q. You stated, however, 30 feet, did you not?

A. I misunderstood your question. The circumference of the reel is measured on the center line of the wire in practice. In that case it would be 30 feet.

Q. Then you want to correct your statement made previously, do you not, as to the circumference of the reel?

Mr. Hopkins: Just add to it that the circumference was determined as you just stated. That is what you want, isn't it?

A. If the circumference was measured as is customary in our work at the center of the wire, or of the cable on the reel, my answer will be correct.

Q. Did you always use a wire of the same size .1 of an inch in diameter?

A. Ordinarily.

Q. Suppose you had measured a channel about 16 feet in width with vertical walls, and found it to be just 16.13 feet wide, and that over half of the area at each side a facing coat of mortar had scaled off to an average depth of 1 inch causing a depression of that depth in the walls which you had not taken into account, how great an error would be introduced into your measurement of width?

Mr. Hopkins: I object on the ground that the hypothetical question is not based on testimony in the record.

A. I believe the error in width would be about ½ of 1 per cent.

Q. That is the area used would be about .955 of the true area, is that correct?

A. The width would be about that.

Q. Yes, the width. Suppose the bottom of a section were smooth and the center of it were ½ inch higher than it was at the sides and that you assume the elevation at the center to be the average elevation, if the water were 2.62 feet deep, how great an error would be introduced?

A. Provided the bottom consisted of two straight lines intersecting at a point in the center ½ inch higher than it was at the edges, the assumption of the depth at the center as the true depth of the section would introduce an error of about .8 of 1 per cent.

Q. Suppose at the top of the water there were waves .2 feet high, the water being 2.62 feet deep, and in determining the depth of the water, the measurement was taken to the trough of the wave instead of to the mean between the trough and crest, what in percentage would be the error in the depth so obtained?

A. Assuming that the area of the section were measured to the trough of the waves, the difference in the cross-section would be about 4 per cent. from what it would be if it were measured to half way between the crest and the trough.

Mr. Hopkins: I object to that question unless the kind and nature of the wave is stated, too.

Mr. Adcock: Q. Are there any other measurements of elevations necessary to be taken, in order to arrive at the area of a water section in the canal mentioned?

A. I do not believe that the product of the depth as de-

termined in that manner multiplied by the width would of necessity give the effective cross section.

Q. What other measurements of elevations do you think would be necessary to be taken into consideration in determining the water section?

A. I know of no other measurements which could be made under those assumptions to increase the accuracy of the cross section.

Q. Including all the sources of error which has been mentioned, what is the total error of the determination of the cross section?

A. The cross sectional area with those assumptions would be in error about 5.3.

Q. You read the testimony of Mr. Schoder, did you not?

A. I did.

Q. There was not any depth stated by him shallower than 2.62 feet of water in the canal that he described, which was measured by him?

A. I see none.

Q. The other depths were from 2.73 to 7.44 feet were they not?

A. They appear to be.

Q. With a depth of 7.09 feet, at which the meter showed a deficiency of 9.5 per cent, what would have been the percentage of error due to cross section, on the assumptions above mentioned?

A. I believe it would be about 1½ per cent.

Q. At how frequent intervals in the vertical are current meter measurements taken in your co-efficient work, say for instance on the St. Clair River. That was the only one that you did any co-efficient work on, isn't it?

A. We measured each tenth depth.

Q. Suppose a vertical to be so measured ten times at the same elevation of water surface, how closely would the river velocity at that vertical be determined; that is at .1 depth?

A. I should say within two per cent.

Q. Suppose 1/5 depth had been observed, instead of 1/10th depths, would the determination have been more or less accurate?

A. It would be less accurate.

Q. What percentage less, or within what percentage of accuracy would it have been?

A. Probably within five per cent.

Q. If 1/20th depths had been used, would the determination have been more or less accurate?

A. With the same number of observations, I should think there would have been practically no difference.

Q. You mean with ten observations at the 1/20th, each 1/20th depths?

A. The accuracy would probably be about 1 per cent. in that case.

Q. In other words it would have been twice as great as the 1/10th depth?

A. Roughly, yes.

Q. You never have made any observations at the 1/20th depths, have you?

A. I never have.

Q. Have you ever calibrated a weir?

A. To a very limited extent only.

Q. Where was this weir?

A. In the hydraulic laboratory of the University of Wisconsin.

Q. How large was it?

A. My recollection of it is that it was about 12 inches.

Q. And that was done simply to determine the method, at that time?

A. It was done as a laboratory experiment, in connection with the college course.

Q. And merely to instruct you as to how it might be done?

A. That was the only purpose of it.

Q. Had no practical benefit?

A. No.

Q. You never have used a weir in measuring water, have you?

A. I have not.

Q. Or you never have compared a discharge measured by a current meter with the same discharge determined by volumetric or gravimetric measurement?

A. No.

Q. Do you know of any one who has?

A. I don't recall any one at present.

Q. Have you ever compared the discharge measured by a current meter with the same discharge determined by an orifice or nozzle?

A. I have not.

Q. You stated that you made in 1912, a reduction of all discharge measurements, did you not?

A. I did.

Q. That you made changes in meter ratings and alterations in gages. Just what did you mean by that?

A. I made a new study of the observations with respect to gage heights and with respect to cross section and meter ratings, and reached somewhat different conclusions in regard to them than were reached in the original reductions. Those changes appeared to be justified by our further knowledge of the hydraulics of the stream in question and the observations were corrected.

Q. What changes did you make?

A. In the discharge of the St. Mary's River, in certain measurements at the International Bridge, the gage which was used was in the canal of the Chandler-Dunbar Power Company, at pier 3, and the elevations of that gage had been referred to the elevations at the automatic gage at Southwest pier by a parallel correction.

The observations indicated that the correction was not the same for all stages, and I applied a correction which was proportional to the stage. I derived new laws for the measurements made in the broad shallow stretch of the river below the rapids by using the increment of flow as determined at the Bridge Section. The increment on the lower sections was indeterminate on account of the small range in stage and large variations in power diversion.

On the Niagara River I made a new tabulation of all discharge measurements, bringing all measurements into a single tabulation. I examined the meter ratings the cross section and the velocity co-efficients, and decided that they could not be improved upon.

Q. That is you mean you examined the data and records and so forth?

A. I do.

Q. You did not re-rate the meters?

A. Oh, no. On the St. Lawrence River I made similar examinations, and there I made certain changes in the ratings used in the computations of the discharge, which seemed to be more logical than those originally used. I also introduced other measurements made by a second meter, which had not been included in the original measurements.

Q. Were those the records compiled by Mr. Shenehon, that you examined on the St. Lawrence?

A. I examined those compiled by Mr. Shenehon.

Q. What did you mean when you said that you changed the meter ratings?

A. The meters were rated at more or less frequent intervals throughout the work, and Mr. Shenehon had used a mean rating for his measurements, being a mean of certain other ratings made during the season. A comparison of the results by the two individual meters indicated that the choice of individual ratings covering certain fixed periods of time would bring the results by the two meters into harmony, and therefore to my mind was more logical than the use of the mean rating covering a season.

Q. That is the mean for the entire season. What did you do down there, take the mean for a certain portion of the season?

A. I took single ratings and applied them to the observations which they logically covered.

Q. When you say logically covered, just what do you mean by that, that were nearest in time?

A. The nearness in time was one consideration.

Q. What was the other consideration?

A. The other consideration was the consistency in the volume of discharge shown by the two meters running abreast, which was done in each measurement.

Q. You mean by running those meters abreast as you did, together, that you could discover, when one meter would get off of its rating?

A. That is what I mean.

Q. And that was one of the things that you took into consideration in making your corrections?

A. It was.

Q. What else did you take into consideration?

A. Those were the only two factors.

Q. The two factors of time, and the performance of the meters?

A. Yes.

Q. Now what did you do with the St. Clair River gaging records?

A. I do not find my report now. To the best of my recollection, we simply listed the discharge measurements.

Q. Did you make any corrections in the meter ratings?

A. I made no corrections to the discharges whatsoever.

Q. Did you follow the same plan that you did with reference to the St. Lawrence?

A. I did not. The subject of the St. Clair River at that

time was being handled by Mr. Richmond, who was doing the same work for that river that I had done for the other rivers, and I accepted his results.

Q. Do you know whether he made any changes in the meter ratings?

A. I could not say.

Q. Now on the Niagara River what changes did you make?

A. I made no changes on the Niagara River discharge measurements.

Q. Neither at the Open Section nor the International Bridge Section?

A. At neither section.

Q. How about the meter ratings?

A. I made no changes in meter ratings, or any others.

Q. Did you make the same examination of the meter ratings with reference to the time and as to other performance of the meters, that you did with reference to the St. Lawrence ratings?

A. I did where it was possible to do so. The method used at the International Bridge Section was somewhat different from that used at the other section.

Q. It was difficult to check it then, is that the situation?

A. On the International Bridge, durin~ a portion of the work, a single meter would be used. There would be no comparison between two meters during a portion of the work.

Q. That was single meter work you used, entirely?

A. No, it was not single meter work.

Q. But they did not run the two meters together, simultaneously?

A. Each discharge measurement depended on a single meter, while at the other sections each discharge measurement depended upon the mean of two meters.

Q. How about the co-efficient work on the Niagara?

A. That depended on two meters, the same as the other rivers.

Q. Has there ever been any co-efficient work done on the Niagara except what Mr. Shenehon did in his early work, and except what Mr. Richmond did on the Split Section?

A. I believe not, by the Lake Survey.

Q. Then in 1907 and 1908, discharge measurements that you made on the Niagara River, you used the co-efficients which Mr. Shenehon had derived?

A. I did.

Q. That was when?

A. Those co-efficients were derived in 1889, I think, mostly.

Q. 1899?

A. 1898 to 1900.

Q. Now you made certain changes you spoke of. What was their effect upon the increment, do they reduce it or increase it in the St. Lawrence River?

A. They reduced the increment.

Q. How about the changes that were made in the St. Clair gagings, records?

A. I made no changes of the St. Clair records.

Q. Mr. Richmond's changes, did they increase or decrease the increment?

A. I am not prepared—

Q. Did Mr. Richmond report his results to you?

A. Not of his reduction, no.

Q. You don't know what they were then?

A. I know the formula that he derived.

Q. You also know that there was an increment derived before, don't you?

A. I know that there was in existence before that a formula, several formulae of the St. Clair River.

Q. You made certain measurements on the Chicago Sanitary Canal this last year, in 1913, you stated. From whom did you receive your instructions as to making those measurements?

A. I received my instructions from Principal Assistant Engineer F. G. Ray, for and in the absence of Colonel Sanford.

Q. What instructions did you receive? Were they in writing?

A. They were.

Q. Have you got a copy of them?

A. I have here the original of the instructions which I received.

Q. Will you read it into the record?

(Witness produces letter which is as follows):

"United States Lake Survey Office

Old Custom House

Detroit, Michigan, Dec. 13, 1913.

From: District Engineer Officer
To: Sherman Moore, J. E.
Lake Survey Office, Detroit, Michigan.
Subject: Discharge measurements, Chicago Drainage Canal.

1. You are instructed to proceed, together with Junior Engineer A. B. Jones, and Surveyman Harry E. Whittelem, to Joliet, Illinois, or to any other point that you may determine as more advantageous, and from there conduct a series of measurements of the flow of water through the rock cut of the Chicago Drainage Canal, this work to be carried out in the manner authorized by the Chief of Engineers in Department letter received this date. (E. D. 91911.)

You will make a careful determination of the flow, using methods similar to those heretofore used by the Lake Survey on similar work in the diversion canals of the Niagara Falls Power Companies. The object of the measurements is to determine the amount of flow during the periods covered by the work to the highest degree of accuracy that is obtainable by observations extending over a period of approximately one week. In connection with the discharge measurement, gages should be operated at or near the mouth of the Chicago River, at the discharge section, and at some point in the vicinity of Willow Springs or Summit, Ill. These gages should be referenced to bench marks of the Illinois River Survey, or with bench marks of the Coast and Geodetic Survey net.

2. Owing to the lateness of the season and the possibility of ice in the canal in the near future, it is desirable to push this work as rapidly as possible, and accordingly you will begin your measurements without delay. As soon as convenient after the work is under way, you will notify the officers of the Chicago Sanitary District concerning the operations that you have in hand, and invite them to be present personally, or by representative, during the operations, if they desire to do so.

3. Upon completion of the work herein outlined, you will return with your assistants to the Detroit Office, and plan to rate meters and reduce the observations as soon as possible thereafter.

For and in the absence of Lt. Col. Sanford,

(Signed) F. G. Ray,
Principal Asst. Engineer."

Q. Have you the letter which you sent to the Chief Engineer of the Sanitary District pursuant to those instructions?

A. I have not.

Q. Have you a copy of it?

A. I have not.

Q. There is a letter referred to from the Chief of Engineers in the letter you just produced dated December 13, 1913, from Mr. Ray, Principal Assistant Engineer to you. Do you remember what that stated?

A. The letter as I recollect authorized the measurements.

Adjourned to Friday, February 20, 10:00 A. M.

Friday, February 20, 1914, 10:00 A. M.

SHERMAN MOORE resumed the stand for further cross-examination by Mr. Adcock and testified as follows:

Q. Did you receive any other instructions than was contained in the letter that was referred to from Mr. Ray?

A. No definite instructions.

Q. What do you mean by "definite instructions"?

A. Mr .Ray and I discussed informally the best methods of work and the best point at which to work, and various things in connection with the work, entirely informally. Those were the only instructions I received.

Q. Do you remember the contents of the letter that you sent to the Sanitary District?

A. It was a very brief letter written hurriedly at the hotel one night in which I notified Mr. Wisner that we were making operations there, making measurements there, and requesting a permit to visit the power house.

Q. That is to the best of your recollection the complete contents of the letter?

A. I could not repeat the contents.

Q. That is you could not repeat it word for word as it was written, but that is substantially the contents?

A. That is substantiallv the contents.

Q. You stated in your direct testimony that there would be a certain effect upon the levels of Lake Michigan-Huron, Lakes St. Clair, Erie and Ontario, by a diversion of 10,000 feet at Chicago. You also stated, gave certain increments for different rivers. Were your conclusions as to the increments and as to the effect upon lake levels based entirely upon the rec-

ords of the observations and measurements of flow of the St. Clair, Niagara and St. Lawrence Rivers?

A. They were.

Q. You also stated that you had made certain experiments to determine the lag, the travel of the crest between Lake Erie and the Bridge Section of the Niagara. Just what experiments did you make?

A. I made a comparison of the records of the automatic gage at Buffalo and at the foot of Austin Street, and comparisons between readings with a staff gage at the International Bridge and the automatic gage at Austin Street.

Q. You ascertained, in your judgment, from those experiments, that when the Buffalo gage rose, for instance, in eight minutes there would be a corresponding rise of the gage at the Bridge Section. Is that correct?

A. I did.

Q. Did you make any experiments to determine how soon the discharge at the Bridge Section would change so as to correspond to a rise or fall of Lake Erie?

A. I made no such experiments.

Q. What is your opinion as to the time within which the discharge would change to correspond to a rise or fall of Lake Erie, as between the two points?

A. In my opinion, the flow of the river at all times is a function of the gage height about eight minutes preceding.

Q. In other words, the flow of the river corresponds or changes as the stage changes, is that correct?

A. That is correct. That is what I mean.

Q. Or eight minutes later. That is the level, the water level at the Section Point?

A. Yes.

Q. You never made any experiments to work that out?

A. I never have.

Q. Upon what do you base that opinion?

A. On experiments made by Mr. Shenehon in the Niagara River, and experiments made by Mr. Sabin in the St. Clair River.

Q. What were the experiments that Mr. Shenehon made? Also state those of Mr. Sabin; describe what they did?

A. In both cases, the meter was run continuously at the section and the velocity as given by that meter was compared with the elevation as given by the gage at the head of the river.

Q. Do you know for how long the meter was run?

A. I could not say.

Q. Did both Mr. Sabin and Mr. Shenehon use the same method?

A. Substantially so.

Q. Mr. Shenehon's experiments were on the Niagara?

A. Yes, sir.

Q. Mr. Sabin's on the St. Clair?

A. Yes.

Q. Did you ever make any experiments of your own, Mr. Moore, on any channel or river?

A. I can't recall ever having made any.

Q. Do you base your opinion upon any work that you did on the Sanitary District Channel of Chicago in the year 1913, in December?

A. That work was corroborative of the fact, although the conditions existing in that canal are not similar in all respects to those existing in a river.

Q. What would be the difference, what conditions are different?

A. In a river, the change in flow is the result ordinarily of a change in the elevation of the lake at the head of the river. In the Drainage Canal, the change in flow was the result of a sudden change in the flow at a point below the section.

Q. What effect would that have?

A. The change of flow in the canal was very large in proportion to the flow, much larger than any change taking place in the elevation of a lake in the same time; and the effect would be complicated by storage capacity in the canal, which I do not believe would enter into the case of a river where the changing stage is very much slower and the river has an opportunity to at once adjust itself through the critical sections to the new conditions.

Q. How about the River St. Clair? Don't you have a change of the stage of Lake St. Clair, which may affect the flow of the St. Clair River?

A. The change in stage of Lake St. Clair is in the open season the result of changes in the flow of the river; and perhaps in that case the comparison is a little better between the river and the canal, although the changes are slow, a long time in taking place.

Q. Do you think the effect would be greater in the case of a large change than in the case of a small change?

A. May I ask just what you mean by "effect"?

Q. The effect at the point observed, that is the point in the river, the discharge section?

(Original question read.)

Mr. Hopkins: Do you mean "quicker"?

Mr. Adcock: "Quicker," rather than "greater."

A. I believe that in the case of a large change, the time required to establish normal conditions throughout the channel might be slightly greater than for a small change.

Q. How does the St. Marys River compare with the conditions in the Sanitary District Canal?

A. They are entirely dissimilar, so far as I can see.

Q. In what way?

A. The St. Marys River corresponds with the Niagara River in the fact that the flow of the river is a function of a single gage above the Rapids.

Q. Doesn't the gage below the Rapids affect the flow in the river?

A. It does not, in the case of the St. Marys River.

Q. Do you mean that to apply to the portion of the river below the Rapids?

A. I mean that any changes in the water surface elevation below the foot of the Rapids will have no effect upon the flow of the river.

Q. You mean that statement to apply to the lower river, to any point in the river and every point in the river?

A. I mean that statement to apply to any point or every point in the river below the foot of the Rapids.

Q. You stated in your direct testimony, I believe, that it would take approximately two hours and a half to three hours to cause a uniform flow of approximately 10,000 cubic feet per second through the entire length of the Drainage Channel and Chicago River from a flow of approximately 4,167 feet, did you not? That was your conclusion?

A. I believe I did state that.

Q. Did you make any experiments in the channel to determine what the length of time would be?

A. I made no experiments for that purpose.

Q. You made approximately 100 measurements in the channel during December, 1913?

A. My results have been reduced in the form of 96 measurements.

Q. The Chicago Engineer Office made certain measurements of flow there, did they not, in that channel?

A. They did.

Q. And they made some measurements simultaneously with you?

A. They did.

Q. Their discharge for the same stage was approximately 10 to 14 per cent. higher than the discharge which you found, was it not?

A. Their discharge at the same time was approximately 10 per cent. greater than what I found.

Q. You state in your report, which was referred to by you on your direct examination as dated January 16, 1914, referring, Mr. Moore, to page 7: "That the maximum flow at Lemont came about six o'clock in the afternoon and corresponds to the overlapping of the day load and the night load at the power house. As a time interval of about 30 minutes between the power house and Lemont is shown by the observations, this load actually occurs about 5:30 P. M."

You also state further down: "The afternoon flow was probably all through the power house, except for small leakages." Did you ascertain just at what time the peak load went on that day?

A. I did not.

Q. Did you ascertain by examination of the flow at the power house the time when the flow was changed to take care of the peak load?

A. I was present when the load on the power house was changed, on one occasion.

Q. But were you present on the day that you refer to in this report?

A. I was not.

Q. So that your statement, then, as to when the peak load occurred, at 5:30 P. M., is based upon what?

A. That statement must not be considered as an actual expression of fact. It is simply a statement of the probable causes for the variation in the load as shown by the measurements at Lemont. The figure of 30 minutes there stated, which is approximate only, was derived by taking the time at which the flow increased at Lemont and the time at which the last generator was synchronized and thrown into service on Sunday afternoon. The operator stated to me that that was the customary time of throwing that load on.

Q. That was what time?

A. I believe the last switch was thrown on that afternoon at 4.45. I have no definite record of that time.

Q. That was Sunday, wasn't it?

A. That was Sunday.

Q. They would not have a day load to carry?

A. They had no day load at that time; that is they had a

small day load. I do not believe it was as large as their ordinary day load.

Q. The time referred to in your report and the portion that I just read, was December 20th, was it not?

A. There is no reference made to any date in the report. It is a general statement of probable conditions.

Q. That was the day, was it not, that you ran your meters all day and all night?

A. On December 20 I ran the meters all day and all night.

Q. Was that the only day that you ran them under those conditions?

A. On December 22 I ran the meters until the load had apparently become uniform in the evening.

Q. What time was that?

A. About 7:30 as I remember.

Q. On the other days how late did you run the meter?

A. About 5:00 o'clock ordinarily.

Q. Will you refer to your notes and your table and give me the exact time that the maximum flow took place at Lemont on December 20?

A. The observations show an absolute maximum flow between 9:48 and 9:58 P. M. The increase in flow at that time over other observations is so small that it may easily be due either to slight errors in the meter or—

Q. How much is the difference in the change?

A. The difference in the flow at that time from what it was at six o'clock is about 5 per cent.

Q. Wasn't that flow some place between 6:06 and 6:37 P. M. in the afternoon of December 20?

A. The maximum flow, as shown by the observations, occurred, as I stated, between 9:48 and 9:58 P. M.

Q. Will you refer to your table attached to your report?

A. The table does not show the maximum single observation.

Q. You have them grouped there in 20 minute periods or half hour periods, and doesn't the maximum flow appear to be between 6:06 and 6:37? When I say maximum, I mean the greatest amount immediately prior to 9:30, that you spoke of?

A. The measurements as grouped in the table between 6:06 and 6:37, show the largest flow recorded to be at the observation made between 21:28 and 21:58.

Q. Just reduce that 21:58 to English?

A. 9:28 to 9:58.

Q. What is the distance between the power house and Lemont?

A. About nine miles, I think.

Q. That is about a quarter of the distance, is it not, from the power house to Lake Michigan?

A. Yes.

Q. Do you think the increase in discharge would travel through the entire length of the canal at the same rate that it traveled between the power house and Lemont?

A. I believe it would, approximately the same rate.

Q. During the time that you were making measurements on the Drainage Channel, did you get the discharge of the channel at Lemont for every hour of the day and night, that is the 24 hour day?

A. No, I didn't.

Q. So that your conclusion as to the daily flow may not be correct; it may be too small?

A. On December 20th, there was an interval of about two hours from 1:00 A. M. to 3:00 A. M. in which no measurements were made. The amount of water flowing at Lemont was practically the same at 1:00 A. M. and at 3:00 A. M. The load on the power house was probably constant. In view of these facts, I believe that the observations show the true amount of water within the limits of the observations flowing through the canal on that one day. There is a possibility, of course, that something happened in those two hours, and that the flow was either diminished or increased. It does not seem to me likely.

Q. You don't know of your own knowledge what happened during that time?

A. I don't know of my own knowledge what happened.

Q. Mr. Richmond spoke in his cross examination about a table of meter corrections for correcting the position of the meter. Have you that table?

A. Mr. Richmond referred to several tables. I don't believe I understand exactly which one you refer to.

Q. He referred to a table that you gave him in connection with his work on the St. Clair at the Gorge Section.

A. I may possibly have that table. I will look and see.

Q. You can look for it after we get through here and give it to us.

A. I don't know that it is in existence.

Q. You don't know that it is in existence?

A. No; it may be.

Q. How was it made up, Mr. Moore?

A. The corrections to the reading of the reel were derived from a consideration of the mean deflection observed over a

considerable period and a table prepared by Mr. Ray showing the amount of correction corresponding to that angle of deflection and compared with the table by Mr. Shenehon, in his 1906 report.

Q. Did that take into consideration the size of the cable?

A. It did not.

Q. The computations to make up this table which you speak of?

A. It did not.

Q. Did it take into consideration whether the cable was rough or smooth?

A. It did not.

Q. Did it take into account the character of the meter at the lower end of the cable?

A. It did not.

Q. Whether it was a A meter or a B meter?

A. It did not.

Q. Assuming that during a certain period of time, say for instance a day, all the water flowing through the Drainage Channel at the Lockport power house passed through the water wheels, and that there was a meter showing the amount of electrical energy, electrical output generated by those wheels; and that at a certain hour it appeared by this meter showing the amount of the electrical output, that it was at a maximum, would that indicate that the maximum flow of water through the power house occured at that time?

A. I think it would.

Q. With the measurements that you have made, and the gagings that you made on the Drainage Canal and Lake Michigan, do you think it would be possible for you to calculate the slopes for various flows through the canal and river?

A. I am very certain that what data I obtained is not sufficient for that purpose.

Q. You state in your report, page 3, paragraph 7, as follows: "When the Lake Survey party left Detroit, it was intended to secure some observations of flow before the officers of the Sanitary District were aware of the work, in order to insure results during normal operating conditions." Did you receive any instructions from Mr. Ray with reference to that, or from Mr. Shenehon?

Mr. Hopkins: Objected to as immaterial.

A. I received no instructions, no definite instructions in regard to that matter. Mr. Ray and I discussed it, and it appeared to be merely precaution such as we have always taken to insure that our results—that is not exactly what I

mean—to have evidence that there was no manipulation of the flow during the time that observations were made.

Q. You didn't have any evidence that there would be any manipulation?

A. We had no expectation that there would be.

Q. You stated also in your report in the same paragraph as follows: "Mr. George M. Wisner, Chief Engineer for the Sanitary District, was at once notified by letter of the purpose of the Lake Survey, so that if he desired he might observe the operations, either in person or through a representative."

Q. Did you notify Mr. Wisner to co-operate or be present by representative, while you were making these observations?

A. There was no specific invitation. I did not consider that such was called for. If he knew the operations were in progress, I expected that if he desired to be present he would feel at liberty to do so.

Q. Did you "notify them (The Sanitary District) to be present personally or by representative, during the operations"?

A. I certainly did not.

Q. You say also in your report: "A representative of the Sanitary District was present during a part of the work"; when was he present?

A. I have no records to show when he was present.

Q. As a matter of fact, did not some one from the Sanitary District appear at the section or near the section where you were gaging for Lemont, for the purpose of making measurements, the very last day you were there?

A. Mr. Blanchard was present at various times, from the start of the observations until the finish of the observations.

Q. How long was he present?

A. I am not certain that he was present every day, but he was present at times for three or four hours at a time.

Q. Mr. Blanchard happened to be at this point when you went there, didn't he?

A. Mr. Blanchard had a party at that point when I went there.

Q. Did you consider that the notification that you gave Mr. Wisner, about which you have testified, a carrying out of the instructions contained in your letter?

Mr. Hopkins: Objected to as immaterial.

A. I so considered it.

Q. You state in the last page of your report, paragraph 31, as follows: "With the possibility of having to calibrate the

power house at Lockport at some future time, for the purpose of supervision of the flow, a reconnoissance of the lower reaches of the canal, and an inspection of the power house was made." Was that contained in any of your instructions?

A. It was contained in no written instructions.

Mr. Adcock: That is all.

Re-direct Examination by Mr. Hopkins.

Q. Mr. Moore, will you explain those inclusive figures given by Mr. Richmond in his testimony as to deflections of the meter cable, which he read from your note books?

A. On one day in the note books, the deflection of the meter cable set down opposite each position of the meter shows a range in value of 4 or 5 degrees, or thereabouts. Those figures are not actual observations. At that time, I was attempting to determine the outside range within which I could expect the angle to fluctuate. I had at that time with me a list of all the observations observed previously, and as each station was occupied, I noticed the inclination at that time, compared it with previously measured inclinations.

Mr. Adcock: Q. At the same station?

A. At the same station, and instructed Mr. Richmond to set down in the note book these figures which to me represented the maximum and minimum deflection which could be expected at that point. Those were used as a basis for determining the correction to the depth of the meter.

Mr. Hopkins: Q. In your opinion, are the cable deflections as testified to by Mr. Richmond from your note books actually observed, any measurement of velocity?

A. The deflection of the cable is an indication in a rough way of the velocity. It is not a measure of the velocity. It cannot be used as a measure of the velocity, because it depends on a great many elements other than the velocity. The depth at the particular time of observation affects the deflection. The size of the wire was not uniform. It was varying constantly. Cables wore out and were replaced by new ones, not always of the same size. The core wire, that is the electric wire on the interior of the cable, carrying the electric current to the meter, was frequently renewed.

Each time this core wire was renewed, the strands of the cable were loosened. For a short period, the cable would probably be larger, and would pull down in use.

There are minor differences in the meters used, and to my

mind the deflection may legitimately be expected to vary over four or five degrees for the same velocity at the same point.

Mr. Adcock: Q. Same size cable?

A. No. To some extent, possibly with the same size cable. Errors of observation also enter into these deflections, which were never determined with any great degree of accuracy. It was considered that an error of two or three degrees in the deflection made absolutely no difference in the positions of the meter, so far as results were concerned.

Mr. Hopkins: Did you ever make anv tests for deflections of a sounding wire to show whether or not Mr. Ray's table was correct, the table you said you used?

A. I have made such experiments under the most extreme conditions.

Q. Tell us about those tests?

A. In off shore sounding, that is in sounding in water over 66 feet deep on the lakes, with a steamer, it had been my practice to limit the deflection of the sounding wire to about 30 degrees, believing that the table was not accurate beyond that point.

I was informed that other parties of the Lake Survey were using angles as high as 45 and 50 degrees, and I questioned the accuracy of results obtained under those conditions; but as the difference between 30 degrees and 45 degrees represents several square miles in a day's work, I made some observations to determine whether the corrections as derived from the table were correct with these large deflection angles. On a smooth, sandy bottom, in about 150 feet of water, with the steamer running at a practically uniform speed, with a deflection angle of about 45 degrees, the soundings would show a variation of only one or two feet from one sounding to the next. Under those conditions, I stopped the steamer in the shortest possible distance, which probably was within 200 feet, and observed the depth with a zero deflection. The depths as read off of the sounding scale, indicated somewhere in the neighborhood of 175 feet. The correction, as taken from the tables, amounted to between 20 and 25 feet. After this correction was applied to the soundings, they agreed within a foot or two of the depth observed with the zero deflection.

There are also in our work cases, a good many cases where lines run with a high angle of deflection crossed lines running at a much lower angle of deflection, but so far as I know, in every case there is no discrepancy appearing in the soundings.

Q. What percentage would that one or two feet be, where you were making that test?

A. A discrepancy of 2 feet in 150 feet would be a little over 1 per cent.

Q. Now suppose your angle of deflection is within the limits used in the soundings for current meter measurements, would there be any such percentage of error, in your opinion?

A. In my opinion the percentage of error would probably be smaller. The observations under extreme conditions show that the theory of the curve taken by the wire is approximately correct, and with smaller angles of deflection of lesser depths, the actual errors would be very much smaller.

Q. In your cross-examination, you spoke of a sounding, an individual sounding at one particular place in the Niagara River, which you thought might be 2 per cent. in error. Am I correct in saying that that 2 per cent. was as to an individual sounding at an individual point?

A. That 2 per cent. was given as a limiting value on the error of an individual sounding.

Q. What is your conclusion as to all of your soundings in the cross section, the percentage of error in spans 3 and 4 at the International Bridge Section in the Niagara River?

A. The mean of the seven soundings in span 3 or of the 11 soundings in span 4, is undoubtedly correct within less than ½ of 1 per cent.

The difference between the soundings made by me and the soundings made by Mr. Shenehon in 1900, at the same points, show a mean percentage change in span 3 of 1/10th of 1 per cent., and in span 4 of 4/10ths of 1 per cent.

Q. Referring to your testimony in regard to certain measurements made by Mr. Schoder and Mr. Turner on the canal at Cornell University, you said that there might be an error of 10 per cent. in the cross section. On cross examination, on certain assumptions, you totaled up the percentage of error in the cross section to 5.3 per cent. Does that change your opinion as to the percentage of error of the cross section, as given in your direct testimony?

A. I still believe that in the determination of the cross section the error might easily be an error of 10 per cent.

Q. On cross examination, you were asked if you ever made any tests of current meters. Do you want to correct that?

A. I assisted in the tests of current meters made in the Detroit River in the spring of 1906, by Mr. Shenehon.

Q. In your cross-examination, you were asked a question as to whether or not the level of Lake Huron had any effect

on the lower St. Marys River. Do you want to say anything further in regard to that?

A. When I speak of the discharge of the St. Marys River, the flow of the river through the Rapids and through the Power Canals is the thought in my mind. Changes in the elevation on the lower river below the Falls, or in Lake Huron, would affect for a short time the actual flow through the portion of the river below the Falls, by changing the amount of storage. That is with the falling stage at the lower end of the river, a certain amount of storage would be withdrawn from the lower stretches of the river and would increase the flow while that was in progress. Similarly, rises would check the flow by increasing the amount of water which went into storage.

The effect for any considerable period would be negligible, and the effect would not be felt on the river above the Falls or above the Rapids.

Q. Now, referring to the Chicago Drainage Canal, do you know how the engineers from the Chicago office did their work? Just explain their method of measuring?

A. I was present while an engineer from the Chicago office made measurements of the flow of water through the canal at Lemont, and he stated to me that that was his customary method.

Observations of velocity were made at .4 depth at points 10 feet apart across the stream. The Engineer Office at Chicago furnished me with a copy of their reduction of these measurements; and from the copy it appears that they assumed that the velocity as determined by the current meter at the .4 depth was the mean velocity in the vertical. They took the mean measured velocity and multiplied it by the cross sectional area to derive the discharge.

Q. Did you determine the vertical co-efficients in the canal?

A. I did.

Q. What percentage of the index velocity, as measured at the .4 depth, represented the mean velocity as to the whole canal, all of the vertical curves?

A. On the Lemont Section, the mean velocity in the vertical was 90 per cent. of the velocity at the .4 depth practically.

Q. What effect would that have upon the total discharge, comparing your total discharge to that made by the Chicago Engineers, United States Engineers?

A. The failure to use the vertical co-efficient would result

in the measurements as made by the Engineer's Office in Chicago, being about 10 per cent. larger than those made by me.

Q. How did their current meter work check with yours as regards measure of velocity?

A. A current rating was made of their meter, in comparison with one of ours, and showed a discrepancy of less than 2 per cent., from which I would judge that their measurements of velocity were probably good.

Q. In cross-examination, you said something about the maximum in the Chicago Drainage Canal, at one period of the day being about 5 per cent. over what it was somewhere around 6 o'clock of the same day; and the difference might be indicated by the current meter. Will you explain that a little bit more fully?

A. It is a fact which is well known to this office, which was pointed out by Mr. Shenehon as far back as 1899, that a current meter is subject to daily variations, which may amount to as much as 2 per cent. The difference between the maximum load as pointed out on that day and the load at 6 o'clock was stated to be 5 per cent. If you assumed that the meter at that time was giving velocities 2 per cent. in error, the actual flow through the canal at this period which was pointed out would be 3 per cent. larger than it was at 6 o'clock, and it would not be larger than at other intermediate times. I simply chose 6 o'clock as a convenient comparison. The 5 per cent. difference is partly difference in flow.

Q. Mr. Moore, your observations as to the rate of travel of waves, as I understood, were from Lemont to Willow Springs. That is correct, isn't it?

A. I base my testimony concerning the time necessary for the wave to proceed from the power house to Chicago on the interval shown between the gages at Lemont and Willow Springs.

Q. Not from Lmont to the power house?

A. Not from Lemont to the power house.

Re-cross Examination by Mr. Adcock.

Q. This Chicago Office that you speak of that made the measurements on the Drainage Canal, is the U. S. Engineer's Office at Chicago, isn't it?

A. It is.

Q. The men in that employ?

A. (No response.)

Q. They used a Price meter, didn't they?

A. They used a Price meter.

Q. In your opinion, their work was not accurate?

A. In my opinion, their measurements of velocity were accurate.

Q. But they did not know how to gage a stream, that is the proposition?

A. They neglected to apply one correction which I believe should be applied.

Q. And in that you differ evidently with the Engineer Office at Chicago?

A. I do.

Q. Now you made some tests with Mr. Shenehon of the current meter in the Detroit River. Just what did you do? Was that where you put fluid into the water and calculated the time and so forth as compared with the velocity shown by the meter?

A. Those were the experiments.

Q. That is simply to determine whether or not the current meter indicated the time during which this colored fluid traveled a certain distance?

A. Whether the current meter indicated the same velocity as that indicated by the movement of the colored water.

Q. Where was that? How far in the water was the current meter suspended, immersed?

A. If you want an accurate statement of that, I will have to look it up.

Q. Just approximately?

A. My recollection is it was about 2 feet.

Q. You were not present when Mr. Turner and Mr. Schoder determined the cross section of the canal at Cornell, were you?

A. I was not present.

Q. You spoke of a table that was prepared by Principal Assistant Engineer Mr. Ray. When did he prepare that table?

A. I don't know.

Q. When did you make the tests?

A. I made the tests last summer.

Q. Mr. Ray was still Principal Assistant Engineer?

A. He was.

Q. You referred to a table just now in your testimony, of the deflections of the meter cable at various points, as I understood, in the cross section, from which you made these entries of 9 to 14 degrees, etc. Have you that table?

A. The entries of from 9 to 14 degrees and so forth were made in a note book. The correction was entered in a table.

Q. You said that you had a list of deflections, showing the deflections at the various points on the verticals that had been observed there, giving the range, and that this was a transcript of those arrangements, as I understood your testimony. If there is such a table, we would like to see it?

A. I don't believe I understood just what you want.

Q. (Question and answer read as follows: "Mr. Moore, will you explain those inclusive figures given by Mr. Richmond in his testimony as to deflections of the meter cable, which he read from your note books?

A. On one day in the note books, the deflection of the meter cable set down opposite each position of the meter shows a range in value of 4 or 5 degrees or thereabouts. Those figures were not actual observations. At that time I was attempting to determine the outside range within which I could expect the angle to fluctuate. I had at that time with me a list of all the deflections observed previously, and as each station was occupied I noticed the inclination at that time, compared it with previously measured inclinations.")

The Witness: That list of deflections referred to was merely a temporary list and was destroyed as soon as the computations were made. The reason for entering the maximum and minimum deflection in the note book was to permit of destroying the list.

Q. How often were these meter cables renewed during a gaging like you did on the St. Clair River?

A. The electric wire in the center of the cable was renewed whenever the insulation became imperfct. It might be two or three days or a cable might last a month, possibly six weeks. It all depended on whether or not the insulation happened to be broken in getting the wire into the interior of the cable.

Q. What was the difference in the size of the cables used in the St. Clair work?

A. One cable was 3/8ths of an inch, as I remember it. That is, it was of the size sold commercially as 3/8th of an inch, and the other one a quarter of an inch.

Q. Which one did you use on the B meter and which one on the A meter?

A. To the best of my recollection, no distinction was made between them. It might be the A meter—

Q. You endeavored, didn't you, to use the same size cable all the time?

A. We did not.
Q. So far as you could?
A. We did not.
Q. You just interchanged from one size to another?
A. Yes.
Q. Just as you happened to have wire around?
A. As we happened to be able to buy the cable.
Q. Do you consider the difference in the size of the wire made any great difference in the deflection?
A. The size of the wire might make some difference in the deflection. I would not care to say how much. I have never made any experiments or computations to show what it would be; but I can conceive of its being as great as two or three degrees easily. It might be more. It is possible it was less.
Q. Then you haven't any very definite idea as to what the difference might be?
A. I have not a very definite idea.
Mr. Adcock: That is all.

Re-re-direct Examination by Mr. Hopkins.

Q. Do you consider the deflections made any great difference in the results of the measurements?
A. The deflections of the meter cable within five or six degrees would have a very small effect upon the actual position of the meter, and the small change in the actual position of the meter would have an infinitesimal effect on the measured flow.

Further Re-cross Examination by Mr. Adcock.

Q. So it was not very important just where the meter was immersed, was it?
A. It was not at all important, within certain limits.

Adjourned subject to notice.

WALDEMAR S. RICHMOND, a witness called in rebuttal on behalf of the Government, was first duly sworn and testified as follows:

Direct Examination by Mr. Hopkins.

Q. State your full name?
A. Waldemar S. Richmond.
Q. Where do you live, Mr. Richmond?
A. Detroit, Michigan.
Q. What is your business or profession?
A. Civil Engineer.
Q. By whom employed?
A. United States Lake Survey.
Q. What education, training and experience have you had?
A. I was graduated from the Massachusetts Institute of Technology in June, 1905. I worked, directely after that, one month for the Pennsylvania Railroad at Pittsburg; eight months with the Widell Finley Company of Chicago, in Dakota and Illinois; two months as assistant instructor in civil engineering at the Massachusetts Institute, and since May, 1906, with the United States Lake Survey.
Q. What training and experience have you had in the measurement of rivers and streams of various kinds?
A. I was for three years ranking Assistant to Mr. Moore, and was with him in all of his hydraulic work except the measurments in December, 1911, and December, 1913.
I had full charge of the hydraulic party for about two months in the fall of 1909, during Mr. Moore's illness; and since July 1st, 1910, I have had full charge in field and office of the hydraulic party of the Lake Survey.
Q. The work that you say you were not engaged with Mr. Moore in, in December, 1913, what work was that?
A. That was the measurement of the Drainage Canal.
Q. And in December, 1911?
A. Measurements of the hydraulic canal at Niagara Falls.
Q. What rivers have you measured, or taken part in the measurement of?
A. St. Marys, St. Clair, Niagara and St. Lawrence.
Q. Now take the St. Clair; how many sections have you been engaged on?
A. On measurements on two river sections and on all the six sections in the Delta.
Q. What sections are they?

A. Near the head of the river, there is Section Gorge; further down, Section Dry Dock, and the six sections in the Delta are named to correspond with the names of the channels.

Q. When was each one of those measurements?

A. Sections Gorge and Dry Dock, I made measurements of in 1908, 1909 and 1910, and the channel sections in 1910.

Q. With reference to what gage were each of these observations made, or were the observations at each of these sections made?

A. In 1910, 11 self-registering gages were maintained. Do you mean what gages were used in final reductions?

Q. Explain in detail just how the work was done?

A. In 1910, the 11 self-registering gages were maintained as I have stated. These were located partly at Port Huron near the head of the river, and along the length of the river as far as Lake St. Clair. Discharge measurements were made at Section Gorge and at Section Dry Dock during practically every month of the seven months of the field season; and on each of the six Delta Sections at five different periods, a little more than a month apart.

Q. To what gage were your discharge measurements referred?

A. In the final reduction, the measurements were referred to a gage right at the foot of Lake Huron, called Ft. Gratiot Lighthouse gage, and to a gage at the foot of the river on Lake St. Clair called St. Clair Flats gage, but through the relation of those two gages to the upstream gage, and gage at Dry Dock.

Q. What do you mean by the upstream gage?

A. The Ft. Gratiot Lighthouse gage.

Q. What was the purpose of these new measurements that you made?

A. They were to increase our knowledge of the hydraulics of the river, to ascertain as definitely as possible whether or not there had been any change of regimen in recent years, and whether or not there was any seasonal change in regimen.

Q. What precautions did you take to insure the correctness of your work; as to gages, for instance?

A. Gages were maintained in the customary manner, all the precautions which I had learned from former work being observed, and in addition extra precaution was taken, in that practically every gage was referred to at least two different bench marks, and levels were run at least three times during the season; that is at the beginning of the work, and

sometime in mid-summer, and again near the close of the work. The gages were very frequently inspected by a trained assistant, who was particularly careful with his watch; the idea being to get the time on the records within one or two or perhaps three minutes; that is as accurately as possible. Unusual precautions were taken in leveling, to the reference points of the gages. An umbrella was used over the level if there was any sun, or was used as a wind shield, if there was the slightest breeze. A spherical rod level was used with the rod. The target was always set, and it was read independently by two persons. Further, an improvement was made in the small type of gage, so that there was no possibility of the record paper slipping.

Q. Now, what precautions were taken as to other elements of the work?

A. All known precautions were observed. In regard to the meter work, some refinements were introduced. In rating the meters, they were suspended two at a time, a thing which has frequently but not always been done by the Lake Survey, so that any irregularity that appeared in one and not in the other was at once noted.

The meters were rated at least twice, you might say, during each rating; that is, when one pair had been about half rated they were taken out; the other pair was half rated, and the first pair was then returned to the water, but in opposite positions, so that the meters had received a cleaning and oiling, and were interchanged in position, during the two halves of the rating.

The same base wire, which is the standard of length that determines the distance factor in the rating, was used in all these ratings, the same identical wire, and the distance between the two marks on it was determined in position at least once during each rating, with a good steel tape.

In measuring velocities in the stream, or discharge measurements, two meters were always run abreast at the 4/10ths depth points as heretofore, but after the completion of a single discharge measurement one meter was invariably changed and the other meter was cleaned and oiled, so that if more than one measurement was made during the day, we had a current rating, a current comparison of the performance of two meters against one other one. The meters were always attended to by myself or my assistant, Mr. Jones; nobody else being allowed to clean them or oil them or have anything to do with the wheel part of the head of the meter.

The contact pins were never changed during the entire season.

The pivot was never molested between two still water ratings. In case of wear, when the wheel began to rub at any point on the meter, the part that was rubbed was immediately filed down, so that the rubbing could not continue. That would not be a part of the bearing.

Mr. Adcock: I move to strike out the portion of the answer which states that he used all precautions that he obtained from other work. It states an improper conclusion of the witness, that he used extra precautions, because that encroaches upon the province of the court, and then that he used unusual precautions, in running levels, the same point with reference to that statement as to the previous one; and that he used all known precautions with reference to certain ratings of the meters. And that a man was selected who was careful with his watch, we object to that as unintelligible.

Mr. Hopkins: Mr. Richmond have you read Mr. Moore's testimony in this case, taken in 1909?

A. I have.

Q. Are you acquainted with the precautions which he said in that testimony he used?

A. I am very familiar with them.

Q. Did you take all of those precautions?

A. I did.

Q. And those that you have mentioned to-day in your testimony?

A. I did.

Q. Who is this Mr. Jones that you spoke of?

A. Mr. Albert B. Jones is a Junior Engineer with the United States Lake Survey. He has been my ranking assistant since July 1st, 1910.

Q. Have you had opportunity to check on his work?

A. I am perfectly familiar with practically all of his work.

Q. Is he a college graduate?

A. He is a graduate of the University of Michigan, class of 1910.

Q. In civil engineering?

A. In civil engineering.

Q. Is his work accurate?

A. It is.

Q. Who were the individuals—

Mr. Austrian: I haven't any objection to your asking if

in the witness' opinion his work is accurate. I do not think you have a right to ask him that.

Mr. Hopkins: I think everything he says is really that.

Mr. Austrian: I do not think you have a right to ask him whether his work is accurate.

Mr. Hopkins: It is a question for you to argue. He said that he had seen all of his work; was very familiar with it.

Mr. Austrian: Will you change your question? It is not a proper question. Otherwise you substitute the witness' opinion for the court's.

Mr. Hopkins: That is you best judgment as to his work, is it?

A. Yes.

Q. Who were the individuals that handled the watch in connection with the gage that you speak of?

A. As a matter of fact I handled the watch myself while Mr. Moore had charge of the party, until the first of July.

Q. What year?

A. 1910, and thereafter Mr. Clarence Theurer, a surveyman with the United States Lake Survey attached to my party made the inspection and handled the watch.

Q. What precautions do you take as to the accuracy of your watch, in discharge work? As to the time elements, what precaution is taken?

A. Watches were compared with standard time as given by some clock in Port Huron, almost daily during the year of 1910, in the endeavor to keep the watches actually used at least within three minutes of correct central standard time.

Q. In discharge work, what precautions are taken to insure the correctness of the time element?

Mr. Adcock: I object to that unless you refer to the Lake Survey work.

A. Time intervals during the velocity observations were ordinarily 120 seconds. These were customarily determined with an ordinary watch with a second hand; but a good stop watch was occasionally used to check the determination by the common watch.

Q. Mr. Richmond, did you investigate for error in the breaking of the electrical circuit?

A. I have never made any experiments to show what the error in making and breaking of registration circuit was, but it can be accurately deduced theoretically. There is a constant error in the registration as practiced in our work. It amounts in the ratings to approximately 1/3 of 1 per cent.

The velocity observations tend to eliminate it, and in certain velocities it is entirely eliminated. There is, however, a residual error in all the discharge work, and it amounts on some sections to as much as .2 of 1 per cent of the discharge.

Q. In which direction is that error?

A. The discharge as recorded is too small, due to that error.

Mr. Adcock: That is your opinion?

A. That is the result of computation.

Mr. Hopkins: Q. What would it be, that same error, in the Third Section or Split Section of the Niagara River?

A. On the portion of that section in the West Channel, it amounts approximately to 1/10th of 1 per cent.; and on the other it is the same.

Mr. Adcock: Q. Do you correct that error in making the computations?

A. It has not been corrected.

Mr. Hopkins: Q. Would that error have any effect upon an increment determined from those observations?

A. Inappreciable.

Q. Now what measurements have you made upon the Niagara River?

A. Upon the Niagara River, I assisted Mr. Moore in his measurements from the International Bridge in 1907 and 1908, and this past summer, I directed the measurement at the Third Section.

Q. Was the work at this Third Section or Split Section done with the same degree of care that you have described as to your late work in measuring the rivers?

A. Yes.

Mr. Adcock: That does not apply to the former work?

Mr. Hopkins: The question was only as to the latter work. The other was already in the record.

Q. I show you Exhibit C, October 8, 1913, consisting of four pages. What is that exhibit?

A. This exhibit appears to be a blue print copy of a letter submitted by me to the District Office of the Lake Survey, being a preliminary report on the hydraulics of the Niagara River of 1913.

Q. What does it contain in detail?

Mr. Adcock: I object to that question as to what it contains. That is shown by the paper itself.

Mr. Hopkins: Q. Describe in a general way what is in there?

A. This letter contains data relative to the measurements on the third Section of the Niagara River.

Q. By whom was it written?

A. By myself.

Q. Does it contain the correct data as discovered by you in the work at the Third Section?

A. Yes.

Q. Does it give the volume of discharge?

A. It does.

Q. What else does it give?

A. It gives certain data about the conditions at the sections, and in general the methods employed in making the measurements.

Mr. Hopkins: We offer that in evidence as Richmond's Exhibit 1, February 4, 1914.

(Document identified by witness was offered in evidence and marked Richmond's Exhibit 1, February 4, 1914.)

Mr. Adcock: I want to object to that, as it appears to be merely a preliminary report; the final report should be produced showing the complete document. It is objected to on the ground it appears to be merely a part of a report.

Mr. Hopkins: Have you made any further report?

A. I have not.

Mr. Adcock: Does that report contain all the data which you have with reference to that measurement?

A. It contains all except the tabulation of the daily mean water surface elevations at the gages.

Q. Does it contain the details of the soundings and coefficient work?

A. It does not go into great detail.

Mr. Hopkins: Q. So far as results are concerned, is it final?

A. It is.

Mr. Adcock: I withdraw the objection that was made.

Mr. Hopkins: I show you Exhibit D of October 8, 1913 (handing witness same), what is that?

A. This appears to be a photographic reproduction of a chart prepared by me showing the relations of revolutions per second to velocity in feet per second, which are the ratings of the four meters used.

Mr. Adcock: That was on the Split Section?

A. Yes.

Mr. Hopkins: That is offered in evidence as Richmond's Exhibit 2 of this date.

(Document identified by the witness and offered in evidence was marked Richmond's Exhibit 2, February 4, 1914.)

Q. I show you Exhibit E of October 8, 1913 (handing witness same). I will ask you what that is?

A. This is a similar reproduction of a chart prepared by me showing the final results of discharge measurements on the two portions of the Split Section, with their relation to elevations at the Buffalo gage, Lake Erie.

Mr. Hopkins: That is offered in evidence as Richmond's Exhibit 3 of this date.

(Document identified by witness and offered in evidence was marked Richmond's Exhibit 3, February 4, 1914.)

Q. I show you another paper, Richmond's Exhibit 4 of this date. Tell us what that is.

A. This is a reproduction of a chart prepared by me showing the cross section of the bottom profile and the transverse curve of velocities at .4 depth for Sections "Wickwire" and "Oakfield," the two portions of the Split Section.

Mr. Hopkins: I offer that in evidence.

(Document offered in evidence and identified by witness, was marked Richmond's Exhibit 4, February 4, 1914.)

Q. Mr. Richmond, will you go into detail as to what you did in the measurements at this Split Section, and what precautions as to accuracy were taken, and just explain in your own way how the work was carried on.

A. These sections having been selected and approved by my superiors, the first work was to determine horizontal distances.

Mr. Adcock: State who approved of it?

A. Mr. F. C. Ray, Principal Assistant Engineer. The first work was to measure horizontal distances, in order to obtain the length across the river and the location of certain signals with respect to this line. In making these horizontal determinations, a good 100 foot steel tape was used to measure a base line about a half a mile long. A system of triangulation was laid out, all angles being read by repetitions, so that each angle was known within a few seconds of arc; and by trigonometric computation, the distances were determined. As a check on these distances, connection was made with the triangulation system of the International Waterways Commission.

This connection on Section Oakfield gave a discrepancy of about 1/10th of a foot in a line nearly half a mile long, and on Section Wickwire the agreement was not quite as good.

The system of ranges was then planned, and the positions of the ranges determined in a similar manner so that definite points on the river could be occupied, by sighting across the ranges which defined the section itself, and another pair which gave a line intersecting. The intersections of the two lines defining any position in the river were never sharper than about 35 degrees, I believe.

On each section, two sets of cut-off range systems were established, one on each shore. In sounding the sections, the Lake Survey steel catamaran was used. A 140 pound, fish shaped iron sounding weight was suspended by a steel wire, about a tenth of an inch in diameter. This was wound on the drum of a reel, by the indications of which, depths to the nearest tenth of a foot could be read. This catamaran was swung in position on a long mooring line, in the customary manner. The sounding wire entered the water exactly on section, and its position on the section was determined by angles from a transit on shore. Deflections above the water of the sounding wire from the vertical were observed. These soundings were reduced in the customary manner, the necessary corrections for deflections, diameter of reel and fluctuation of stage being applied.

Mr. Hopkins: Q. What possible error might come in the distances, that is length of section and so on?

A. The length of either section would not be in error by one-half a foot.

Q. What is that as a percentage?

A. Not over .03 of 1 per cent.

Adjourned to Thursday, February 5, 9:30 A. M.

Thursday, February 5, 1914, 9:30 A. M.

WALDEMAR S. RICHMOND, resumed the stand and testified further on direct examination as follows:

Mr. Hopkins: Q. With what degree of precision, in your opinion, did you get the area of the cross section at the Split Section?

A. Within ½ of 1 per cent.

Q. Is that true as to both of them?

A. For each section.

Q. In your sounding, did your weight go down plumb, or was there a deflection; if so about how much?

A. The mean deflection was 1 degree from the vertical; the maximum three degrees.

Q. That is in the sounding wire?

A. That is the deflection of the sounding wire.

Q. Now your velocity co-efficient, with what degree of precision did you ascertain that?

A. The mean of the co-efficients was within ½ of 1 per cent.

Q. Your velocity as ascertained by the current meter or meters?

A. Average velocities were good within .2 of 1 per cent.

Q. What in your opinion is the degree of precision of the whole work, the measurement of discharge, of the volume of flow?

A. I believe the final result to be good within 1 per cent.

Q. You mentioned something about undertaking new measurements for the purpose of further refinements if possible. What were your results in that regard; and what effect if any did it have on the final result?

A. The result, the final result was not appreciably better, in spite of the attempted refinements.

Q. How was this indicated in the Niagara River, with refernce to other measurements, or in comparison with the former measurements?

A. I should say that the close agreement of results was a good indication of this.

Q. Do you know what care of refinements were taken in the earlier measurements in the Niagara River?

A. I have read carefully the records of that work, and I am fairly familiar with the refinements taken.

Q. What were they?

A. Without going into detail, they were fairly similar to those of the later work.

Q. Now you said you had made some measurements in the St. Lawrence River. When did you do that work in the St. Lawrence River?

A. In 1911 and 1913.

Q. With what degree of precision do you think the Lake Survey now has the volume of discharge of the St. Lawrence River?

A. For the mean stage of observation, within 3 per cent.

Q. I don't believe I asked you this question: What was the condition of the water at the Third Section of the Niagara, with reference to your measurements?

A. The surface water was smooth, and the indications were that there was no particular perturbation in the flow.

Q. Did you make any examinations for that? First, what was the character of the bottom?

A. The bottom was mostly gravel or clay, on each section.

Q. There is a certain sand bar some little distance above this section, isn't there?

A. Yes, there is a bar in the neighborhood of half a mile above each section.

Q. Did you know that at the time you selected the section?

A. I knew that.

Q. What effect in your opinion does that bar have upon the condition of the water where you measured it as to perturbation?

A. I believe it would have no appreciable effect at the sections.

Q. Was there any curvature in the stream at those places?

A. There was a rather flat curvature at each section.

Q. What effect would that have upon the section with reference to your measurements?

A. I think the effect would be inappreciable.

Q. Do you have any way of knowing whether there are perturbations in the water beneath the surface, by indications of the meter or any other way?

A. Yes, there is a very good way.

Q. Just what is it?

A. It is the indication of the electric register of the meter.

Q. Were there any such indications in these places?

A. On the bottom runs, the registers indicated some irregularity.

Q. How about the 9/10ths depth?

A. The 9/10ths depth did not show much if any.

Q. What in your judgment would be the effect of that condition near the bottom on the whole work, as to the whole volume of flow?

A. The whole volume of flow might be indicated slightly smaller than the true volume.

Q. What do you mean by slightly, in percentage?

A. I don't think it would amount to a quarter of 1 per cent. of the river flow.

Q. You take that into consideration in giving your opinion that the whole work was accurate within 1 per cent.?

A. I do.

Q. Did you take into consideration in giving your opinion of the 1 per cent. error of the whole work, the make and break of the electric current?

A. I did.

Q. Did you state which way the error was?

A. It might be either way.

Q. Mr. Richmond, what in your opinion is the increment of the Niagara River?

A. At mean stage of observation 21,500.

Q. Just what work have you done, in connection with the increments of these various rivers, and what study have you made?

A. I derived the more recent equations for the St. Clair River, and have done some computing on the derivations for the Niagara River; have derived the later equations for the St. Lawrence River.

Mr. Adcock: Q. The increment is based upon your computations and the computations of others?

A. Yes, sir.

Q. From the measurements in evidence here, the records of measurement?

A. (No response).

Mr. Hopkins: Q. Have you studied the work of the other men in the Lake Survey Office, in this matter of increment?

A. I have.

Q. And compared that with your own observations and computations?

A. Yes.

Q. And the increment you have given for the Niagara is the result of all of your knowledge in connection with that matter?

A. It is.

Mr. Adcock: What I wanted to ask you is whether or not your statement as to what you believe the increment of the Niagara River to be is based alone on the observations or records of observations and measurements in the Niagara River that have been referred to in the evidence?

Mr. Hopkins: Q. Mr. Richmond, just tell us what it is based upon, your opinion as to the increment?

A. It is based upon my knowledge of what the observations were, what the results were and what the computations were, having myself assisted in making some of those computations.

Q. Referring to Haskell's Exhibit 1, February 3, 1914, how does the increment as it appears on that exhibit from the plotted observations compare with the one you have given?

A. The increment given here is 21,900.

Q. In your opinion Mr. Richmond, is the line showing an increment a straight line or a curve, that is for the Niagara River?

A. For the Niagara River I believe there is practically no difference.

Q. You say that you yourself have computed an increment for the St. Lawrence River?

A. I have.

Q. What is that increment?

A. For a stage of 245 at Oswego, about 21,000.

Q. What elevation was that?

A. 245.

Q. Is that mean?

A. That is the nearest even foot from the mean.

Q. What range of stage did you get in the St. Lawrence approximately?

A. A little over two feet for mean measurements.

Q. Is this increment from your own measurements?

A. It is.

Q. In your opinion within what degree of precision is the increment that you have given in the Niagara River?

A. I believe it to be within 5 per cent. of the truth.

Q. And the increment of the St. Lawrence River?

A. Within 8 per cent.

Q. You say you have computed an increment, too, for the St. Clair River?

A. I did.

Q. What is it?

A. For a stage of 579 at Lake Huron, 20,300; for a stage of 581, 22,700, with normal conditions in Lake St. Clair.

Q. That would indicate that the increment in the St. Clair is more correctly represented by a curve than a straight line?

A. I believe it is.

Q. Now on the St. Lawrence?

A. In my opinion a curve fits the observations a little better than a straight line for the St. Lawrence.

Q. Now, Mr. Richmond, these increments are all derived from open season conditions, aren't they?

A. They are,

Q. What would the increment for the entire year be as compared with the increment you have given?

A. It would be somewhat less, due to ice effects in the rivers.

Q. What rivers do you refer to in that particularly?

A. I believe the St. Clair and Detroit Rivers to be affected much more than the others.

Q. How about the St. Lawrence?

A. There is some effect. I don't know how great it is.

Q. For a given diversion say at Chicago, which continues all the year around, in your opinion would the effect upon the lakes as far as level is concerned, be greater or less when the whole year is considered than the increment you have given?

A. The effect would be greater because the increment must be less.

Q. Now in your work at the St. Clair, that you have conducted, what did you do with reference to passing boats?

A. I made practically no velocity observations when passing vessels were on or near the sections.

Q. Were there a good many boats passing?

A. Yes.

Q. How about the Niagara and the St. Lawrence in that respect?

A. There are comparatively few boats passing on the Niagara. On the St. Lawrence, the condition is somewhat intermediate between the Niagara and St. Clair.

Q. What is the length of time it takes for a crest at the Fort Gratiot Lighthouse to affect the Gorge Section in the St. Clair?

A. Approximately one minute.

(Table entitled: Time interval required for change of Lake Stage at Ft. Gratiot to be felt at various gages and sections is set out below:)

From Fort Gratiot Lighthouse Gage.

Gage or Section	Miles	Time	Time to Nearest 10 Minutes	Minutes per Mile.	Section from Channel Entrance Miles.
		h min			
Section Gorge	0.45	1			
G. T. R.	0.80	2			
M. B. R.	2.45				
Dry Dock (Dunford)	4.65				
Dry Dock (Section)	5.10	16	20	3.14	
St. Clair	13.8	44	40	3.19	
Marine City	21.6	59	1:00	2.73	
Roberts Landing	25.6	1:09	1:10	2.69	
Section Sny	27.4	1:14	1:10		0.3
Section Bridge	30.8	1:32	1:30		0.8
Herson Island	32.4	1:37	1:40	2.99	
Salt Block (gage)	33.7	1:41	1:40	3.00	
Section M. C.	33.9	1:42	1:40		1.5
Section Salt Block	34.6	1:44	1:40		
Section Bassett	34.7	1:44	1:40		0.3
Section S. E. Bend	34.9	1:45	1:40		
St. Clair Flats	39.4	2 Approx	2 Approx	3.05?	

Q. Referring to table above, just describe that?

A. That is a table showing the distance along the thread of the stream from Ft. Gratiot Lighthouse down the St. Clair River, and the corresponding time intervals of wave propagation down the river.

Q. Suppose the level of Lake Huron at Ft. Gratiot Lighthouse should rise 1 foot. How long would it take that effect to appear in the St. Clair River at various gages along the river?

A. At the G. T. R. gage—

Q. That is the Grand Trunk Railroad gage is it?

A. Yes—two minutes; at Section Dry Dock gage 16 minutes; at St. Clair 44 minutes; at Marine City 59 minutes; at Robert's Landing 1 hour and 9 minutes; at Herson Island gage 1 hour and 37 minutes; at Salt Block gage 1 hour and 41 minutes, and at St. Clair Flats gage approximately 2 hours.

Q. At what places were measurements made there of flow?

A. I mentioned the automatic gages.

Q. Which one is the Gorge Section?

A. The one that was mentioned previously, as taking 1 minute.

Q. Which one is the Dry Dock Section?

A. 16 minutes.

Q. What was the name of it?

A. Section Dry Dock gage.

Mr. Hopkins: Q. And the Third Section where you made measurements?

A. The intervals to those gages were determined by proportion from the nearest self registering gages.

Q. What is the time approximately?

Mr. Adcock: Are those the gages on the gaging section at the Delta you speak of?

A. Yes. At Section Sny in the Chenal Ecarte 1 hour and 14 minutes; at Section Bridge in the Blind Channel 1 hour and 32 minutes; at Section Bassett in the Bassett Channel, 1 hour and 44 minutes; Southeast Bend Section in the South Channel, 1 hour and 45 minutes; at Section M. C. in the Middle Channel 1 hour and 42 minutes; at Section Salt Block in the North Channel, 1 hour and 44 minutes.

Q. What is the rate per mile in the transmission of this wave effect?

A. Approximately three minutes to the mile.

Q. In your judgment does the velocity effect closely follow that?

A. I believe it does.

Q. What was the time interval on the St. Lawrence River between the Galops Rapids and the Three Point Section?

A. Between the Ogdensburg and section gages you mean?

Q. Yes?

A. The interval is two hours and 20 minutes.

Q. Did you determine that yourself?

A. That is the interval determined by Mr. Shenehon. I have re-determined it to be 2 hours and 15 minutes.

Q. What is the distance?

A. About 17 miles.

Q. What is the rate per mile?

A. That is about eight minutes to the mile.

Q. Why is that slow as compared with the St. Clair?

A. It must be due to the presence of the rapids in that reach of the river.

Q. Mr. Richmond, in your opinion with what precision can large streams be measured as to volume of flow, as compared with small streams?

A. Large streams can be measured at least as accurately as small streams.

Q. Have you read the testimony of Mr. Schoder and Mr. Turner in this case?

A. I have.

Q. Do you have in mind the tests made by them of the Haskell current meter, as testified to by them?

A. Yes.

Q. In your opinion do those tests show that the current meter is inaccurate?

A. No.

Q. Why not?

A. The tests were made under conditions such as never prevailed at gaging sections used by the Lake Survey. The meter is said by Mr. Turner to have vibrated both horizontally and vertically. In all my use of a current meter, I have never seen any such vibrations. The perturbation at the sections, as judged by the photographs is very much greater than at any section the Lake Survey has ever used. It is not comparable at all.

Q. Do you think that it is possible to determine with accuracy the cross section in that canal that they testified about under the conditions that appear in their testimony?

A. It was testified that waves of at least .2 foot amplitude were occurring on these sections. I do not see how the cross sections, at least of the shallower sections, could have been determined within about 2 per cent.

Q. How about the portion of the water nearest the bottom and the sides?

A. Meter measurements were not taken closer than ½ foot to the sides and bottom of the canal.

Q. How about the velocity coefficient?

A. I don't understand that coefficients were used, but if they were, I do not see how they could have been determined very accurately under those conditions.

Q. I suppose that in a large river you would have a wave effect of as much as two inches or more, wouldn't you?

A. Never during the determination of a cross section. That work is always done on a day when the river surface is perfectly smooth.

Q. But suppose you had a river of a depth of 30 feet as compared with a canal of 3½ feet, what would be the difference?

A. The percentage of error in the smaller channel would be very much larger.

Q. Why?

A. The size of waves on the river would have to be comparable with the size of waves in that canal. The waves would have to be—

Mr. Adcock: Assuming a depth of 30 feet?

Mr. Hopkins: Yes, assume a depth of 30 feet.

A. The waves would have to be considerably larger. I could not state just how much.

Q. Can you give it roughly? Is it your opinion that the wave would have to be about 2 feet high to be comparable?

A. It would have to be in that neighborhood.

Q. How about the weir measurements themselves in these tests?

A. There is some doubt as to the accuracy of the weir, inasmuch as it was calibrated by a double transfer from a smaller weir.

Mr. Adcock: Q. Mr. Richmond, do you know how it was calibrated?

A. As given in the testimony by Mr. Schoder and Mr. Turner.

Mr. Adcock: I move that the statement of the witness be stricken out as to conclusions regarding what the testimony of Mr. Schoder and Mr. Turner shows. The court will determine that.

Mr. Hopkins: Q. Is your statement in reference to the weir Mr. Richmond based upon what was in the testimony as to the way they determined the accuracy of the weir?

Mr. Adcock: I object to that.

Mr. Hopkins: Q. Upon what was your statement as to the weir based?

Mr. Adcock: You can ask him a question assuming that it was calibrated. I do not want the witness to state what Schoder's and Turner's testimony shows.

Mr. Hopkins: Assuming that the weir was calibrated in the manner stated in the testimony of Mr. Schoder and Mr. Turner.

Mr. Adcock: I object to that.

Mr. Hopkins: What is your opinion as to the accuracy of the weir measurements?

Mr. Adcock: I object to that question on the grounds stated.

Mr. Hopkins: Now go ahead.

A. I do not see how the weir could be assumed to be accurate.

Mr. Adcock: I move that answer be stricken out.

Mr. Hopkins: Q. Do you recall a part of Mr. Schoder's testimony—

Mr. Adcock: You can ask him a question assuming that the weir was calibrated in a certain way. If your assumption corresponds, in the opinion of the court, with what Mr. Schoder and Mr. Turner stated in their testimony, then your answer is all right.

Q. (Question read) —wherein he is speaking of the precision of observations at various sections, and speaks of having made more observations at some sections than at others?

A. Yes, at a section 41 feet below the baffles, he measured discharges number 6 and 9. The discharge as given by the standard weir differed only about 1 per cent. in those two measurements.

The mean depth at the section differed less than ½ of 1 per cent. There was a difference by the current meter measurement of approximately 7 per cent. This, Mr. Schoder attributes to the difference in precision of the current meter measurements. He measured velocities at more points in the section on discharge number 9, but did not measure any closer to the sides or bottom. This discrepancy, amounting to about 7 per cent., is much greater than the discrepancies found in Lake Survey measurements, and seems to me to indicate a lack of precision in his work.

Mr. Adcock: You say it seems to have shown lack of precision; you mean he did not do his work accurately, is that right?

A. Yes.

Mr. Hopkins: That is all.

Cross-examination reserved.

Wednesday, February 18, 1914, 9:30 A. M.

WALDEMAR S. RICHMOND resumed the stand and testified further as follows:

Mr. Adcock: Q. On the Oakfield Section, Mr. Richmond, the hydraulic section, what was the width of the river at that point?

A. About 2,200 feet.

Q. How many panels?

A. There were 11 panels, in addition to the two end areas.

Q. You sounded that section in the same way you did the Wickwire Section?

A. Practically the same.

Q. Every $7\frac{1}{2}$ feet?

A. The soundings were a little closer together, averaging 5.6 feet apart.

Q. About how often were they?

A. 5.6 feet.

Q. Is that the closest, or the average?

A. That is the average in the 11 panels.

Q. What is the greatest depth?

A. 37.7 feet.

Q. What was the greatest inclination, maximum inclination of your sounding wire?

A. Three degrees.

Q. Where was that found?

A. At the maximum depth.

Q. How many days did it take you to do the soundings on both sections?

A. As I recall it, soundings were made on four different days on Section Oakfield, only part of the day being used each time. On Section Wickwire, the sounding was completed on one day, I believe in about half a day.

Q. On the Oakfield Section, were those days consecutive days?

A. They were not.

Q. How far apart were they?

A. I haven't the record of that. I could not say exactly.

Q. Was there the same condition of wind and water and so on as to turbulence, at the time you made the soundings?

A. Practically the same.

Q. Did you have any record of the conditions on the day the soundings were made?

A. In the field books, I believe there are records of the weather conditions, and with reference to the quietness of the surface water.

Q. What was the index velocity in the vertical, where the maximum deflection occurred on Oakfield?

A. It was about three feet a second. I haven't the exact figures.

Q. Was the water the greatest depth at that point?

A. I do not think any vertical came at the point of maximum depth on the section, exactly.

Q. How near the maximum depth was the nearest vertical?

A. I should say offhand within one or two feet.

Mr. Hopkins: Q. Do you mean one or two feet in depth or one or two feet laterally from the deepest point?

A. I mean difference in depth between the maximum depth and the depth on the vertical nearest to it.

Mr. Adcock: Q. What would be the effect of this additional depth that you speak of on the velocity?

A. Do you mean what difference would there be in the mean velocity at the point of greatest depth and at the vertical?

Q. Yes, and at the nearest vertical?

A. I should think the mean velocity would be slightly greater at the deepest point.

Q. I presume that there is some point in a river where the mean velocity is greater than the mean of any other point?

A. In the vertical, yes.

Q. Is that usually at the greatest depth, or do other conditions enter in?

A. It is influenced somewhat by other conditions, mainly whether that greatest depth continues upstream and downstream at the same point.

Q. Do you know whether that was the case here at this point of the river?

A. I do not know, within that small limit.

Q. What was the vertical where the greatest deflection occurred; that is the number of the vertical so that we can have it for reference?

A. I haven't that exactly, but I believe it would be one of the central verticals.

Q. You numbered the various verticals, didn't you?

A. They were numbered.

Q. I didn't know but perhaps you might know the number of the vertical, where the greatest deflection occurred?

A. I haven't that here so that I could give that.

Q. Was it vertical eight?

A. I don't believe so.

Q. What was the vertical where the deflection of the sounding wire was two degrees, and what was the depth at that point on the Oakfield Section?

A. I could not state that without reference to the original data. I have no record of it here.

Q. You can't answer that question without referring to your notes?

A. Without consulting the field books, and I am not sure I could then.

Q. On Oakfield, what was the number of the vertical where the greatest deflection in the sounding wire existed?

A. Vertical five was about 18 feet from the point of maximum sounding and maximum sounding deflection.

Q. What was the depth at that point?

A. At vertical five, for the stage of this plot, the depth was 36.4 feet.

Q. What was it at the deepest point, 37?

A. 37.7.

Q. What was the stage to which you refer?

A. 2.40 on section gage.

Q. What was the deflection on vertical 5?

A. Sounding deflection?

Q. Yes?

A. It was between two and three degrees. The deflection was not measured actually at that point.

Q. And the deflection at the deepest point was three degrees?

A. Three degrees.

Q. What was the deflection on vertical eight?

A. Between zero and one degree.

Q. What was the depth on that vertical?

A. About 21.9 feet at gage 2.40.

Q. What is the actual elevation to which 2.40 corresponds?

A. It has not been referred to actual elevation.

Q. What was the index velocity on vertical five for the elevation mentioned?

A. 2.99 feet per second.

Q. What was it in 8?

A. 2.54.

Q. Referring again to vertical 8, how many times was vertical 8 traversed by the meter, current meter?

A. Eight times.

Q. How many times were the verticals traversed at the other stations?

A. Four times on each except vertical 9, which was traversed six times.

Q. Why were eight traverses used at vertical 8?

A. Because, owing to a slight uncertainty in the smoothness of the bottom, the results by four traverses were not quite as good as on the other verticals, so that more traverses seemed desirable.

Q. That was your determination, was it?
A. Yes, it was.
Q. At the time you made these different traverses?
A. Yes.
Q. What percentage of the index velocity was the mean velocity by the first four traverses on vertical 8?
A. I don't think I ever computed that. I haven't those computations now.
Q. Then how did you compare the individual results with average results?
A. A plot was made in the field of the mean of those first four traverses, and from an inspection of that plot, as I recollect, I determined that more observations were desirable; but I do not think that the coefficient was computed.
Q. That is you compared this plot with the plot of other verticals, did you?
A. Yes.
Q. Did you think there was any greater inconsistency in 8 than there was in 4?
A. Yes, there was.
Q. You are sure of that statement, are you?
A. Yes, I feel sure of that.
Q. From calculations that you have made or from what?
A. Simply from inspecting the plot, and noting the amounts by which individual points did not fall on the smooth curve drawn.
Q. Take vertical 6, what do you say as to that?
A. Vertical 6 was measured with four traverses only, and it was considered satisfactory.
Q. Did you consider that the agreement of traverses in 6 was as good as that in 8?
A. The final result at 8, does not seem to me to be quite as good as on 6.
Q. Are you referring to the first four traverses or all eight traverses?
A. I was referring to all eight.
Q. Will you refer to the four in answering the question?
A. It would answer for that also.
Q. What is that?
A. It would answer for that also.
Q. Compare that with one vertical.
A. Compare 6 with one of 8?
Q. 8, the first four traverses of 8?

A. I should say the result of the first four traverses on 8 was not as good as on 1.

Q. Will you compare the results of the first four traverses on 8 with the results of the second four traverses on vertical 8?

A. From an inspection of the data here, I should say the last four were a little more harmonious among themselves than the first four.

Q. What was the difference in percentage of the coefficients?

A. That has not been computed.

Q. Wasn't it approximately two per cent.?

A. I could not say very accurately without computing. I do not think it would be that great.

Q. How great do you consider it would be?

A. It looks to me as if it might easily have been 1 per cent.

Q. Might it have been two per cent. approximately?

A. I could not say definitely, without making a computation.

Q. How long will it take you to make a computation?

A. An hour, perhaps.

Q. Assuming that the difference between the results of the first four and the second four traverses has been approximately two per cent., how far would that adopted average have been from the mean of the first four?

A. It would have been in the neighborhood of half of the two per cent.

Q. Approximately 1 per cent.

A. In that case, approximately 1 per cent.

Q. Suppose that eight traverses had been made on all the other verticals, and the result had been to make a similar change in the percentage for all of them, how much would the discharge have been changed?

A. Assuming the condition you state, the total discharge would have been changed 1 per cent.

Q. If the difference was .9 of 1 per cent., the answer would be the same, is that correct?

A. The vertical coefficient enters as a direct factor.

Mr. Hopkins: Q. Mr. Richmond, that 1 per cent. as to all of them, was that assuming that that one per cent. of error would be on the same side in every one of them?

A. That was what I understood from the question, the assumption that they made, that the coefficient should be 1

per cent. smaller or larger in each case. That of course is not the case.

Mr. Adcock: Q. What was the vertical where the deflection of the sounding wire was approximately two degrees?

A. The deflection seems to have been practically two degrees at verticals 3, 4, 5, 6 and 7.

Q. What was the depth in each one of these verticals, referring to the 2.40 mentioned?

A. Those depths scaled from the chart are: Vertical 3, 32.4; vertical 4, 35.1; vertical 5, 36.4; vertical 6, 34.8; vertical 7, 33.8.

Q. What was the index velocity in each vertical? I think you have stated the index velocity of 5?

A. Vertical 3, 2.9 feet per second; 4, 3.0; 5, 3.0; 6, 3.0; 7, 2.9.

Q. If you wished to obtain the ratio of the mean velocity to the index velocity in any vertical, by arithmetical computation, what weights would you give to the observation at each point in the vertical?

A. If I understand your question rightly, in this case a single one of my observations at the bottom was given the weight of ½, and the others practically a weight of 1.

Q. Did you make any distinction between the weight of .2, .4, .7, .8 depths?

A. I think not.

(Question and answer immediately previous to last one read.)

Mr. Hopkins: Include in your answer what you understand the question to mean?

The Witness: I don't believe I understood the question.

Mr. Hopkins: Answer the question. Strike out the answer.

A. My answer was based on observations. I simply meant that I took a weight of one-half for the bottom observation, because there were two observations and the mean was used as against single observations on the other points.

Mr. Adcock: Q. You understand—

A. I would not attempt to do it the way I understand from your question, because I don't think it could be done accurately.

Q. That is by arithmetical computation?

A. Yes.

Q. Did you ever try it that way?

A. I never did.

Q. How great an error would result if the observations were properly weighted by this arithmetical computation?

A. If they were weighted with due regard to the form of a

smooth curve drawn through the plotted points, I don't see why a fairly accurate computation could not be made.

Q. Taking into consideration the form of the curve, what weights would you give to the different observations at different points?

Mr. Hopkins: That is a question on the arithmetical feature.

Mr. Adcock: Yes.

Mr. Hopkins: I object to that on the ground he said he would not determine it that way.

Mr. Adcock: No, we are asking him by arithmetical computation.

Mr. Hopkins: That is the form of my objection. He said he would not determine it that way.

Mr. Adcock: If he wants to express the opinion this is not as good a way as some other way, that is another proposition.

Q. (Last question read.)

A. It seems to me that the weights would have to vary with the individual curve, and that method of computation in the end would amount to the same thing as the method I have used.

Q. Do you mean that you would weight them differently in each vertical?

A. Yes.

Q. On what theory would you do that?

A. Because each vertical is of different depth from every other one, and the bottom run is always at a certain distance from the bottom and, therefore, the percentage difference, on a shallow vertical, comes considerably higher up the curve than on a deep one.

Q. How much difference would that make in the result for changes of depth from 20 to 30 feet?

A. As practiced by the Lake Survey, the bottom depth in a 20-foot vertical would be at a point about 93 per cent. of the depth from the surface, and in the 30-foot vertical about 95 per cent.

Q. How much difference would that make in the discharge, if both were given the same weight?

A. If I understand the question, there would be very little difference.

Q. How great an error would result if you gave the surface a weight of 1; .2 depth a weight of 2; .4 a weight of 2; .6 a weight of 1½; .7 a weight of 1; .8 a weight of 1; .9 a weight of 1, and the bottom ½?

A. For the average condition on Section Oakfield, I think

the error in the co-efficient would be in the neighborhood of 2 per cent.

Q. If all verticals were treated in this way at a single section, would a comparison of the results indicate the relative values of the ratio of mean to index velocity?

A. I think not, because the depths differ so much, and this error would change rapidly with change in depth. It would be fairly accurate for verticals of the same depth.

Q. How great changes occur at a single station? Confine your answer to a single vertical?

A. Confining my answer to a single vertical and dealing with the separate traverses of it, that seems to me to be a fair method of comparison.

Q. What is the ratio of the mean velocity to the index in the several verticals of the Oakfield section?

A. For vertical 1, .934; vertical 2, .908; vertical 3, .909; vertical 4, .918; vertical 5, .912; vertical 6, .918; vertical 7, .917; vertical 8, .911; vertical 9, .915; vertical 10, .914; vertical 11, .860.

Q. What is the mean of the scalings of each vertical?

A. The mean abscissa for each curve constructed is as follows: Vertical 1, .9250; vertical 2, .9044; vertical 3, .9062; vertical 4, .9223; vertical 5, .9097; vertical 6, .9172; vertical 7, .9148; vertical 8, .9133; vertical 9, .9147; vertical 10, .9138; vertical 11, .8716. Those are not really the mean of the scalings as the question states. I tried to state it so as to show that. They are the areas divided by the depths.

Q. And to reduce this to the co-efficient, this has to be divided by the scaling at the .4 depth?

A. Scaling at the .4 depth.

Q. Now, in these observations you used the Haskell current meter?

A. I did.

Q. That is the meter that the Lake Survey has used in their work?

A. I had four Haskell meters of the B type.

Q. What is the B type as compared with the C type, or some other type?

A . I don't recollect having seen any but the A, B and E types. The A meter is a larger meter arranged for determining directions of the current as well as velocity. The E meter is similar to the B, but smaller.

Q. Has the A meter a larger wheel?

A. No, the wheel is the same.

Q. What is it that is larger about the A meter?

A. The body is longer, and the central part is expanded to form a chamber in which a mechanism is located for determining deflections when the meter is out of sight, down in the water.

Q. That is the A meter?

A. That is the A meter.

Q. The B meter is not what is known as a direction meter?

A. No, the A is the direction meter.

Q. And the B meter is the meter that was used in this work, as well as on the other work of the Lake Survey, in connection with the gagings of the different rivers mentioned?

A. The A meter has been used, but it was not in this work that I am speaking of.

Q. When was the A meter used?

A. It was used by Mr. Shenehon in his Niagara River gagings; by Mr. Moore in his Niagara and St. Clair gagings.

Q. Have all the observations on the St. Clair and Niagara River been taken with the A meter?

A. Partly with the A, and partly with the B.

Q. What proportion of them were taken with the A meter?

A. Less than one-third on the St. Clair River. On the Niagara River about one-half of Mr. Shenehon's observations, I believe, were taken with the A meter.

Q. Did he use both meters at the same time; both types in his work?

A. Yes.

Q. Does the A meter indicate the direction in the vertical plane?

A. It can be used to indicate direction.

Q. How would you mount it to indicate direction in the vertical plane?

A. There is no change in the mounting; simply a matter of connecting up the electrical mechanism and operating it.

Q. Were those connected up for that purpose and so used in the work on these different rivers mentioned?

A. Not as far as I know.

Q. Did you misunderstand the question as to whether it indicated direction in the vertical plane?

A. Apparently I misunderstood your question.

Q. Do you wish to explain or correct your answer as to whether it would indicate direction in the vertical plane?

A. This meter will not indicate any deflection which means a pointing up or down.

Q. How was this meter suspended, in your co-efficient work

and in your other work on making these observations on the Wickwire and Oakfield Sections?

A. The meters were suspended in a similar manner to the sounding weight as already described, except that a quarter inch steel table was used.

Q. How heavy a weight was on the bottom of the meter?

A. On Sections Wickwire and Oakfield, the regular 40-pound weights were used with the meters.

Q. On all the verticals?

A. On all velocity measurements.

Q. Could you see the meter as it was suspended in the water at the time you were taking your velocity observations?

A. I could see the meter down to a depth of perhaps 6 feet; not below that.

Q. Would that be at the .1 depth, say, in the deeper sections?

A. That would be below the .1 depth.

Q. But not down to the .2, would it?

A. I could not say, but I doubt if we saw the meter at the .2 depths.

Q. Did you observe the deflection of the wire upon which the meter was suspended?

A. We did.

Q. What was the greatest deflection?

A. The greatest deflection I find is 12 degrees on vertical 5 for the bottom and .9 depths.

Q. For the bottom and .9 depths?

A. Yes.

Q. That is at Oakfield?

A. Section Oakfield.

Q. That was the deepest panel, wasn't it, deepest station?

A. That was the deepest.

Q. At the other stations, what was the deflection for the bottom and .9 depths?

A. The deflections were as follows: Vertical 1, 2 degrees; vertical 2, 4 degrees; vertical 3, 7 degrees; vertical 4, 10 degrees; vertical 5, 12 degrees; vertical 6, 10 degrees; vertical 7, 10 degrees; vertical 8, 5 degrees; vertical 9, 3 degrees; vertical 10, 1 degree; vertical 11, no degrees.

Q. That was at what depths, 9/10ths depth?

A. 9/10ths depth and bottom.

Q. Did you have any method by which you were able to keep the meter when it was submerged in the water in the proper direction?

A. The meter itself is constructed so as to point in the direction of the current.

Q. That is it has a tail to it?

A. It has.

Q. And that is intended to keep the wheel towards the current?

A. Yes.

Q. How accurately did you consider you could place your meter, say in the vertical at the .4 depth?

A. I believe that it was always within .2 of a foot of the proper depth.

Q. Did that apply to all positions in the vertical?

A. I think it would, yes.

Q. The deflection which you mentioned here, was that the deflection in the co-efficient work observed?

A. It was observed, yes.

Q. And the deflections which you gave were the deflections observed in the co-efficient work?

A. Yes, and at the bottom depths.

Q. And at the bottom depths. Did you observe the deflections after you had made the co-efficient work and in taking the velocity observations in the various verticals?

A. These deflection angles were observed usually during the first traverse of the vertical.

Q. In each case?

A. In each case.

Q. When you took a velocity observation at a particular station, you submerged your meter at the .4 depth, did you not?

A. You mean in measuring discharge?

Q. Measuring the discharge. I am not now referring to the co-efficient work?

A. Yes, in discharge measurements, both meters were suspended at the .4 depth.

Q. That is two meters were suspended?

A. Two were used abreast.

Q. How far apart?

A. They were four feet apart.

Q. In your co-efficient work do I understand you to say that you observed the deflection in each traverse of the vertical, or just the one traverse?

A. Usually only during the first traverse, I think.

Q. So you did not compare the deflection during the first traverse with the deflections during other traverses of the vertical, in co-efficient work?

A. Sometimes, but not as a general rule.

Q. Did you in this work out here at Oakfield or Wickwire?

A. As I recall it, we did compare some of the deflection angles on the deeper runs, but I do not see it recorded in the records.

Q. When you made a discharge observation at a station, or in making the discharge observations at the various stations, did you place the meters at the same point in the panel, each panel?

A. The steering wheel of the catamaran was held on station, this bringing the positions of the two meters practically in the same location.

Q. Each time you made a discharge observation?

A. Each time, yes.

Q. Was this point assumed to be the center of each panel, or the middle?

A. Not in all cases.

Q. Well, what determined the position or the point in the panel?

A. The station was located either in the middle or near the middle of each panel and was marked out in the river by intersecting range lines from the shore.

Q. How close to the middle was this point where you submerged your meter?

A. In the panels which were 100 and 200 feet wide, the station was in the middle. In the panels whose width was 150 feet, the station was 70 feet from the mid-stream side of the panel.

Q. What panels were 100 feet and 200 feet and what were 150 feet, at Oakfield?

A. Panels 1, 10, 11, were 100 feet wide. Panels 2 and 9, 150 feet, and panels 3 to 8, inclusive, 200 feet wide.

Q. Did you submerge the meter at any time in any other points in these different panels than the points where you mentioned? A. No.

Q. So you don't know what the velocity was during the time that you were taking these discharge observations at other points in the panels than the ones where you submerged your meter, as you have stated?

A. Not by actual measurement.

Q. How accurately was the steering mechanism held on the vertical?

A. I should say it was very infrequent that the steering wheel was more than 2 feet from the station position.

Q. How long did it take you to do the co-efficient work on Section Oakfield?

A. About five days.

Q. How long would it take you to make a discharge observation at Oakfield, or how long did it take you, an average?

A. About two hours and a quarter.

Q. Did you observe the deflection of the wire when you were making a discharge observation?

A. No.

Q. At .4 depth?

A. No.

Q. You didn't calculate that deflection at all?

A. No.

Q. When did you compare the deflection when you were making one discharge observation at a given station with the deflection while you were making a similar discharge observation at another time on the same station?

A. It was not observed or compared; it was too unimportant.

Q. That is, you considered it unimportant?

A. I did.

Q. Did you ever do that in your work?

A. Not on those sections?

Q. In any section?

A. Frequently in other sections where it becomes a matter of importance.

Q. But in your judgment, in doing this kind of work, in view of the conditions at this particular point or in this particular section, you thought it was not necessary, is that correct?

A. The correction would have been less than .01 of a foot, an amount that we could not set off on our apparatus.

Q. How far were the meters from the steering wheel of the catamaran?

A. Fifteen feet forward of the steering wheel.

Q. Upstream or downstream?

A. Upstream.

Q. How much would the catamaran swing with the wind at 35 miles an hour?

A. I don't believe I understand your question.

Q. Well, if the wind during the making of an observation was, say, east, northeast, 35 miles an hour, what effect would that have on the catamaran in the Oakfield Section, as to its parallelism with the axis of the stream?

A. I think the catamaran when held on station would point very slightly differently from what it would if there was no wind; I think that difference would be a very small amount.

Q. About how much would it affect the position of the meter?

A. I do not believe it would affect it a foot.

Q. What anchors did you use?

A. I didn't use the side anchor at all.

Q. Just had the single anchor?

A. But on the two stations nearest the end I used side lines to the shore. The central stations, we swung on the head anchor, and kept on position by the steering mechanism. It is a very simple matter.

Q. Now the method which you have outlined here, which you used in the Split Section of the Niagara River is substantially the same method which was used on the St. Clair, Niagara and St. Lawrence Rivers?

A. Substantially, yes.

Recess to 2:15 o'clock P. M.

After Recess 2:15 P. M.

WALDEMAR S. RICHMOND resumed the stand and testified further on cross-examination as follows:

Mr. Adcock: Q. You have some sheets there which show the percentage discharges of the various verticals, I believe 21 in all, in the Oakfield and Wickwire Sections?

A. Percentage velocities, yes.

Mr. Adcock: I would like to get copies of those. I ask that they be identified as Richmond's Exhibit A, consisting of 21 sheets.

(Percentage discharges of verticals, consisting of 21 sheets, marked Richmond Exhibit A, February 18, 1914.)

Q. Was the co-efficient work done at the same time that you made your discharge observations?

A. The co-efficient measurements followed the discharge measurements immediately.

Q. Immediately followed them. Then the co-efficient work and the discharge observations on Wickwire and on Oakfield Sections were carried on between July 30th and August 12th, all done in that time? Is that correct? That is 1913.

A. Did you say on both sections?

Q. Yes?

A. Between July 30th and August 27th.

Q. What was the range of the stage of Lake Erie during that period?

A. From 572.2 to 573.3.

Q. How long does it take to do the coefficient work on a particular vertical?

A. Something like two hours for all the work.

Q. Have you determined coefficients in other sections on other rivers?

A. I have made the measurements and determined coefficients on other sections, yes.

Q. What ones?

A. I did a part of the work for Section Gorge on the St. Clair River; most of the work for the six Delta Sections on the St. Clair River, and remeasured some verticals on Section Three Points on the St. Lawrence River.

Q. What were the maximum depths at these several sections?

A. The maximum depth on Section Gorge was 62½ feet; Section Sny, 28 feet; Section Bridge, 8½; Section Bassett, 31; Section Southeast Bend, 56; Section M. C., 35½; Section Salt Block 46½; Section Three Points, 60.

Q. Have you observed any difference in the coefficients as to whether they were in deep or shallow water?

A. Yes, there is some difference.

Q. Just describe the difference?

A. In deeper water the vertical curve follows a more vertical direction into the eight and sometimes nine-tenths depths, so that the mean velocity is a greater percentage of the index velocity. The resulting coefficient for .4 depth is larger for the deep curves.

Q. In a particular vertical, then, if there is a change in stage, the coefficient would change, would it not, if the stage of the water level was higher there would be a change in the coefficient?

A. It would not change appreciably within the range of observations we observed.

Q. You are speaking now of the Oakfield and Wickwire Sections?

A. Of any vertical that I ever measured.

Q. Suppose a change of three feet in a 30-foot depth, what would you say as to that?

A. I believe theoretically there would be a change, but I believe it would be smaller than could be used in our observations.

Q. How small a change could be used, then, in your observations?

A. We record our coefficients to tenths of one per cent.

Q. Is it your belief that a change of three feet in a 30-foot depth would not change the coefficient .1 of 1 per cent.?

A. I don't think it would.

Q. Have you ever made any calculations?

A. I have never made any calculations myself.

Q. Assuming that there would be a change in the coefficient, the use of a common coefficient for all elevations would give a smaller discharge at the high elevations and a larger discharge at the low elevations, is that right?

A. Assuming those conditions, that would be the tendency, I would say.

Q. Did you do any sounding in the Gorge Section on the St. Clair River?

A. I did.

Q. How often was that sounded?

A. The average distance between the final soundings, I believe would have been between five and ten feet.

Q. What was the width of the river at that point?

A. On Section Gorge 1010 feet.

Q. What was the deflection of your sounding wire at the 62½ feet depth, which you said was the greatest depth?

A. 20 degrees.

Q. What was the size of the wire and the weight?

A. The wire was the regular steel piano wire used by the Lake Survey, about .1 of an inch in diameter. The weight was the standard 140-pound castiron sounding weight.

Q. What was the index velocity, that is the velocity at the .4 depth?

A. About 6 feet a second.

Q. Give us the percentage velocities for the different depths observed in this vertical?

A. I haven't that data. I could not give that.

Q. Have you got it here in the office so that you could get at it?

A. I have the following percentages, which I have scaled from a blueprint copy of the plot of this vertical four Section Gorge. For the surface observation: 98.6; at .1, 100.4; at .2, 100.8; at .3, 100.3; at .4, 100.0; at .5, 98.1; at .6, 98.1; at .7, 95.0; at .8, 93.4; at .9, 85.3, and bottom 60.5.

Q. Have you a 15-degree deflection there in the sounding wire on the Gorge Section?

A. It was probably as much as 15 degrees.

Q. Where the deflection is 15 degrees?

A. The deflection of the sounding wire would probably have been as great as 15 degrees.

Q. What is the deflection of the meter cord at that station four?

A. I presume you want the greatest deflection, at the bottom.

Q. Greatest deflection?

A. 29 degrees.

Q. That was the .9 and the bottom?

A. No, that is the bottom.

Q. What was the weight on the meter?

A. 140 pounds.

Q. Was that at the station where you had your 15-degree deflection or where you had your 20-degree deflection of the sounding wire?

A. That was at vertical four.

Q. The sounding wire deflection was 15 degrees at that point?

A. I said I thought it would be about that.

Q. This was where you had a sounding deflection of 15?

A. Approximately.

Q. What was the greatest depth in that panel?

A. (No response.)

Q. These velocities you gave us were on Station Four?

A. Those were on Station Four.

Q. What station was this where you had 62½ foot depth and a 20-degree deflection?

A. That was 25 or 30 feet west of the vertical four.

Q. What vertical was it?

A. There was no vertical observed at that point.

Q. The velocity was not measured at that point?

A. No.

Q. How near that point was the velocity measured?

A. On vertical four.

Q. What was the depth of vertical four?

A. 61.9 at stage 580.

Q. Then there was a difference of five degrees in the sounding wire between 62½ feet and 61.9?

A. I didn't say that. You asked if the deflection was in the neighborhood of 15 degrees, and I said I thought it was that great.

Q. No, I asked you what was the greatest deflection of the sounding wire on the Section Gorge, and I understood you to say 20 degrees?

A. Yes.

Q. And that was the deepest point, 62½ feet?

A. Yes. Then you assumed this 15 degree deflection on

vertical four for the sounding wire, which I said was probably somewhere near right.

Q. No, I did not assume that. Then what was the deflection of the sounding wire at vertical four?

A. I have no record of that, but I should say it was between 15 and 20 degrees.

Q. Then if at 62½ feet it were 20 degrees, at 61.9 it would be very close to 20 degrees, in your opinion would it not?

A. That sounds reasonable.

Q. Now have you got a vertical there where the deflection was 15 degrees, on the Gorge Section?

A. I could not say as to that. I haven't the data at all.

Q. It is available here, is it not?

A. I think I can find it. It will be quite a task; we have to find the sounding and computation books both.

Q. (Question read as follows: "Now have you got a vertical there where the deflection was 15 degrees on the Gorge Section"?)

A. The sounding wire deflection was 15 degrees on verticals 3, 5 and 6.

Q. What was the depth?

A. For stage 580 on vertical three, the depth was 54½ feet; vertical five, 55½ feet; on vertical 6, 47 feet.

Q. How many verticals did you have on that hydraulic section?

A. Ten.

Q. What was the index velocity on these verticals, at the stage mentioned?

A. Vertical 3, about 6.2; vertical 5, 6.1; vertical 6, 6.5 feet per second.

Q. What were the percentage velocities at the several depths on each vertical, 3, 5 and 6?

A. I have these percentages scaled roughly from the blue print. They are as follows:

For vertical 3, surface 96.7; .1, 98.7; .2, 100.7; .3, 101.0; .4, 100.0; .5, 97.5; .6, 94.6; .7, 89.4; .8, 85.0; .9, 74.8; bottom 61.6.

Vertical 5: Surface 101.0; .1, 102.0; .2, 101.8; .3; 100.9; 4, 100.0; .5, 98.6; .6, 96.9; .7, 95.5; .8, 93.1; .9, 83.9; bottom 64.8.

Vertical 6, surface 96.4; .1, 97.8; .2, 98.8; .3, 99.9; .4, 100.0; .5, 99.9; .6, 98.8; .7, 96.7; .8, 91.4; .9, 82.4; bottom 57.2.

Q. How many traverses did you make of the verticals on this hydraulic section?

A. What amounted to about 18 traverses on each vertical.

Q. What was the deflection of the meter cable in verticals 3, 5 and 6, that is the greatest deflection?

A. For the bottom depth on Station 3, 23 degrees; station 5, 27 degrees; station 6, 17 degrees.

Q. What was the weight, 140 pounds?

A. 140 pound weight.

Q. How do you account for such a difference in the deflection between those different verticals, when the deflection of the sounding wire was substantially the same in each vertical?

A. I think it is due largely to the difference in conditions between the action of the current on the sounding weight and wire and the action on the meter and the wire. It is due partly to the fact that these observations were made at different times, and presumably at somewhat different stages, and are averages.

Q. That is the degrees of deflection are averages. Is that the point?

A. Yes.

Q. Well what are the conditions that you think will operate on the meter that would not operate in the same way on the sounding wire or sounding apparatus?

A. On vertical 6, the observed velocity at the bottom is less than that on 5 and 3, and consequently the action on the meter tending to swing it downstream would be somewhat less.

Q. Is it probable that the velocity was the same, substantially the same at that point, when the sounding weight was submerged?

A. I could not say; if the sounding was not taken on the same day, the distribution of velocities would be about the same, but the actual velocities in the vertical plane would be somewhat different and the sum total result on the length of wire submerged might be a little different.

Q. Well then, on different days, the deflection of the meter wire might be different?

A. It would be a little different.

Q. That would mean then a difference in distribution of velocity, wouldn't it, over that vertical?

A. No, I don't mean that.

Q. Can you explain your answer a little further and state just what you do mean?

A. It seems to me that the effect of the current on the wire and the cable is not due directly to the distribution of

velocities. The impulse acting on the wire or cable at any point varies probably more as the square of the velocity than the velocity itself, and for different depths and different inclinations of the wire, we have the uncertainty due to the fact that the current does not strike the wire or the cable normally.

Q. Well, do I understand then that the current would strike the cable to which is attached the sounding weight differently than the cable to which is attached the meter, causing this difference?

A. It seems reasonable to me that even for the same inclination, the effect on a twisted wire cable might be somewhat different from that on a smooth cylindrical wire.

Q. To the extent of approximately 50 per cent. difference?

A. But I think that this discrepancy you speak of is partly due to errors of observation.

Q. Well then within what degree of accuracy do you consider that the deflections were observed?

A. For the bottom velocities at this section, I think there might be an error of two or three degrees.

Q. That would be approximately 15 per cent. then?

A. That would be something like 15 per cent. It might be in either direction.

Mr. Hopkins: That is 15 per cent. of the angle?

A. Of the angle.

Mr. Adcock: Q. Now take these same verticals, 3, 5 and 6, what was the deflection of the meter wire at the index points, .4 depth?

A. At .4 depth on vertical 3, the deflection of the meter cable was about 7 degrees; on vertical 5, about 9 degrees, and on vertical 6 about 7 degrees.

Q. That was the first traverse?

A. No, that was the average of several values that I just found in the book.

Q. How many times did you observe the deflection on vertical 3, at the .4 depth?

A. I could not say. It was observed a good many times and was not always recorded.

Q. Have you any records there of different observations of the deflection of the meter wire at .4 depth on the vertical?

A. I find in this note book three records of the deflection of which we are speaking.

Q. That is on vertical 3?

A. That is on vertical 3.

Q. What were the deflections?

A. Two of those were measured with one of the B meters, and they are each 7 degrees. The other was measured with an A meter and it is 12 degrees.

Q. What was the velocity observed at the time the meter was submerged at the .4 depth and the deflection was 7 degrees in both cases?

A. The velocities recorded are for the A meter, 6.2 feet per second, for the B meter, 6.6 and 5.8.

Q. That is the B meter was where the deflection was 7 degrees?

A. Two cases of 7 degrees; one velocity is 6.6 and the other 5.8.

Q. Can you give me similar information as to verticals 5 and 6?

A. For vertical 5, I find five records of the deflection as follows:

12 degrees, velocity 6.2. 12 degrees, velocity 6.1. 9 to 14 degrees, velocity 6.4. 10 degrees velocity 6.3. 5 degrees velocity 6.2.

For vertical 6, the following:

10 degrees, velocity 6.8. 10 degrees, velocity 6.2. 7 to 11 degrees, velocity 6.2. 7 degrees, velocity 6.7.

Q. What do you mean by 7 to 11 and 9 to 14 degrees?

A. That is what is recorded in the bock.

Q. You mean that the deflection was somewhere between 9 and 14 degrees? It might be 9 and might be 14, or 7 to 11 as the case might be?

A. I don't recall the circumstance and I doubt if I made the observations, but my interpretation would be that the deflection varied during the measurements there, and it was watched by some observer.

Q. What period of time would be taken up in making the measurement?

A. That would cover a period of about five minutes.

Q. So it is probable that the wire was swinging back and forth between 9 and 14 degrees deflection?

A. I would not say that it swung back and forth. It probably swung from 9 to 14 or from 14 to 9.

Q. 9 to 14 and from 14 to 9, back?

A. One way or the other; might not have reversed at all. I don't know.

Q. And it might have?

A. It might have for all I know.

Q. What would that indicate in your opinion, that is that condition of the wire moving about as you suggest?

A. There might have been some unsteadiness in the catamaran at that time. I don't see what else would do it.

Q. What unsteadiness of the catamaran would cause such a condition?

A. The catamaran might have started to move from position and it would have been brought back with a sudden turn of the wheel.

Q. Might there have been a change in velocity? That is at that point, at that time, which would cause that condition?

A. There is some change in velocity, but not enough to account for it on that theory.

Q. Have you examined the records of that measurements so that you are able to state that, or do you state it from general belief and experience?

A. That was a general belief. That one reading is á mere incident out of hundreds of readings.

Q. There was a similar reading in vertical 6 recorded, wasn't there?

A. Not quite as wide.

Mr. Hopkins: Q. As I understand, Mr. Richmond, this is all based upon your guess as to what that 9 to 14 and 7 to 11, is, isn't it?

A. I do not recall the observations, and I doubt if I made them. They are simply given—

Q. Of your own knowledge, you do not know what that means then?

A. I don't know exactly, no.

Mr. Adcock: Q. Now these deflections that you have stated and the velocities were observed during the coefficient work, were they not?

A. Some of those were during the coefficient work and some during discharge.

Q. How many were observed during the coefficient work. I mean approximately; you do not need to figure it up?

A. On Section Gorge, discharge work was almost always carried on simultaneously with coefficient work, and probably on about half of these coefficients were being measured.

Q. Were all the observations that were taken at the .4 depth used for discharge measurements?

A. As I recall it, they were.

Q. So the observations for the coefficient work were not taken separately from the observations to determine discharge?

A. Not except in one or two instances.

Q. Was the same type of meter used?

A. As I remember, we had three B meters and 1 A meter in that work, and they were interchanged in various ways.

Q. What was the weight of the B meter and its apparatus as compared with that of the A meter and its apparatus?

A. Roughly 30 or 40 pounds.

Q. The difference?

A. Yes.

Q. In favor of which one?

A. The A meter is heavier.

Q. Does the A meter furnish greater resistance to the water than the B meter?

A. In my opinion, it does.

Q. The wheel is not any larger, is it?

A. The wheel is the same size and same shape.

Q. What is the particular thing that would furnish greater resistance?

A. The body of the meter previously described, in which the deflection mechanism is encased.

Q. Was there a heavier weight on the A meter than there was on the B meter?

A. I believe the weight was about the same. I am not sure on that point.

Q. Have you ever made any experiments to determine whether the A meter furnished greater resistance than the B meter?

A. No.

Q. Do you know of any experiments?

A. I do not.

Q. How many discharge measurements did you make on Section Gorge?

A. About 180 complete measurements were made while I had charge of the party.

Q. If the A meter furnishes a greater resistance to the current and would drive further downstream as a result when submerged than the B meter, you would have to use a different table would you in determining the position of the A meter than in determining the position of the B meter?

A. Not within the accuracy with which we set depths.

Q. How accurately do you set the depths?

A. We attempted to set them to the nearest tenth of a foot. They were probably always within two or three tenths.

Q. How about 60 feet of water?

A. The bottom depths were rather easily set because it was customary to lower the meter until it touched bottom and then raise is about .3 of a foot so that it was just clear.

Q. How near did the depth as indicated by the meter, lowered in the manner you just described, coincide with the depth as determined in your sounding operations?

A. Depths could not be determined as accurately by the sounding with the meter as with the sounding wire.

Q. Within how closely did they agree?

A. I never have examined the data to see how closely they did agree.

Q. You have tables, haven't you, showing the percentage velocities and index velocities for each traverse of the vertical in all the sections on the Gorge, all the verticals on the Gorge, similar to those that you furnished on Oakfield and Wickwire?

A. Such tables are supposed to be in the office files, but recently I was unable to locate them.

Q. Would you try and produce them tomorrow for us?

A. I know I cannot produce them. Mr. Ray has made an extended search for them and cannot find them.

Q. Did you participate in any of the discharge measurements on the Niagara and St. Lawrence Rivers, in addition to what you have mentioned?

A. I don't understand that question.

Q. (Question read.)

A. Yes, as already stated.

Q. Were the discharge observations on the St. Clair River as accurately made as those upon the Niagara and St. Lawrence Rivers?

A. I believe they were.

Q. Referring to the Niagara River, do you think they were just as accurately made as they were on the Niagara River?

A. I think the St. Clair work was as accurately done as the Niagara.

Q. It was the same class of work?

A. It was supposed to be the same class of work as nearly as we could do it.

Q. How did the sounding work on the St. Clair River compare with that on the Niagara River, as far as precision is concerned?

A. I am not familiar with the sounding on the Niagara River, except on the Split Section.

Q. You know that the soundings on the St. Clair were done accurately, don't you?

A. I have every confidence in them.

Q. You do not know about that on the Niagara. What percentage of error do you believe to exist in the soundings on the St. Clair River?

A. I believe that the cross section of Section Gorge was determined within 1/2 of 1 per cent.

Q. In what direction is this error?

A. I have never thought but what it could be in either direction.

Q. It is liable to be too small or too large?

A. That is my present opinion.

Q. Take the width of the section, was that determined accurately on the St. Clair, the Gorge Section?

A. Very accurately, yes.

Q. You think as accurately as that of the Niagara?

A. Yes.

Q. Do you think there is any percentage of error in the determination of the width of the section on the St. Clair, Gorge Section?

A. It would be considerably less than .1 of 1 per cent.

Q. In which direction?

A. In either direction I should think.

Q. .1 of 1 per cent. would be how much? That is about 1100 feet there.

A. Well, it would be about 1 foot.

Q. How is this width determined?

A. By triangulation from a base line measured on shore with a steel tape.

Q. Well, possibly the court might not know much about triangulation. Suppose you just explain what you mean by that.

A. In determining the width at Section Gorge, as I recall it, a station was established on the line of the section at a point perhaps 100 feet from the shore. From there a line was measured in a northerly direction with a 100 foot steel tape.

Q. Northerly direction, what did that bear to the axis of the river?

A. The river was flowing nearly due south at that point. I do not remember whether that base line was measured with a fifty meter wire or a 100 foot steel tape, but the line meas-

ured was about as long as the distance across the river. Signals were erected at both ends of this line and at a point on the west shore of the river right near the waters edge. Transit angles were then read by repetitions at the two stations on the east shore and from the two measured angles and the included base line, the triangle lengths were computed by trigonometry. Then for a given stage the distance to the waters edge from the points on the section on each side of the river were measured. The sum of these deducted from the side of the triangle along the section gave the width of the section at the water surface.

Q. Were the meters or meter ratings accurately made in the work on the St. Clair that you mentioned, the Gorge Section?

A. They were accurately made, yes.

Q. And you consider as accurately as the meter ratings on the Niagara?

A. Yes, I think they were.

Q. Was there any percentage of error in those ratings?

A. I don't know to what you refer, unless to the constant error of registration of which I have already testified.

Q. In which direction is that constant error? Do you mean to say that the ratings have an accuracy of 100 per cent., except for the constant error that you mentioned?

A. I do not mean to say that the ratings are perfect. That is what your question assumes.

Q. Within what degree of accuracy are they made?

A. I believe that the rating curve at any point is within .3 of 1 per cent. of the true line.

Q. Which way is that error?

A. That error is likely to be one way or the other.

Q. There is no greater error in the ratings of the meters on the St. Clair gagings than on the Niagara, is there?

A. I don't think there is.

Q. How about the coefficient work, was that as well done on the St. Clair River as on the Niagara, in the gagings?

A. I believe it to be as well done.

Q. What percentage of error do you believe exists in the coefficient work on the St. Clair?

A. I believe the weighted mean coefficient for Section Gorge to be within 1/2 of 1 per cent.

Q. Which direction is that error in the coefficient work?

A. It might be either way.

Q. Now referring to the observations constituting a gag-

ing on the St. Clair River, were they as accurately made as upon the Niagara?

A. I believe they were.

Q. Do you believe any error to exist in those observations?

A. Only within the limits of accidental errors, as I have already stated.

Q. What is the amount?

A. If the various elements entering—

Q. I mean the error of the individual observation, that is the velocity determination?

A. I don't believe I understand your question.

Q. Well, you submerged your meter to a .4 depth, didn't you at each vertical, in making a gaging?

A. You mean how much error might there be in a single discharge observation?

Q. Yes, in the various verticals, or in the average of a large number of verticals, considering the discharge work as separate from the coefficient work. You have told us what the error might be in the coefficient work. That enters into your final result—

A. I can't say whether you are talking about the final discharge or the actual velocity observation during the discharge measurement?

Q. The actual velocity observations made during a single discharge observation, leaving out all question as to error in the coefficient work, error in the soundings, error in the determination of the width of the Section, and the other errors which you have mentioned heretofore; that is a single discharge observation?

A. I believe that the average velocity in a discharge measurement was determined within less than one-half of 1 per cent.

Q. In which direction is that error?

A. I think I have made a mis-statement in that.

Q. If you have, just strike out the answer, if you want to state it over again.

A. I would rather change that statement to 2 per cent. either way.

Q. Two per cent. either way?

A. Yes.

Q. That is the average velocity of a series of observations?

A. No.

Q. Just state what you mean the two per cent. error to apply to?

A. I believe that the average velocity measured during a single discharge measurement is within two per cent. of the truth, either way.

Q. You mean a complete discharge measurement that you have spoken of, that takes a couple of hours or so?

A. Yes, I mean what ordinarily would be two, 2 minute runs on each of the ten index points.

Q. That is the .4 depth?

A. That is the average of 20 observations ordinarily.

Q. That is you believe that the average would be within 2 per cent. of accuracy at the .4 depth?

A. For one single discharge measurement.

Q. And you are referring to the Gorge Section here, are you not?

A. I was referring to the Gorge Section.

Q. Where you had 11 verticals?

A. 10.

Q. What would be the error of 50 discharge observations on that section, made in the same manner that you mentioned?

A. I believe the observations, as I stated, would tend to balance, and the mean of 50 would be very close to the truth.

Q. Within what degree of accuracy?

A. My opinion at the present time is that the average result would be within .1 of a per cent.

Q. .1 of 1 per cent.; and that might be either way?

A. Either way.

Q. Now in that connection, you mean the average velocity, don't you?

A. Yes.

Q. You mentioned the observations made of the gagings in connection with the St. Clair observations in your direct examination. Were those observations carefully, accurately made?

A. They were.

Q. And as accurately as you think in connection with the Niagara gagings?

A. I believe they were.

Q. Do you believe there is any percentage of error in connection with the gage readings?

A. There is some error. I don't think that individual readings would often be more than .05 or .06 of a foot in error, and of course thousands were taken.

Q. In what direction?

A. Either way.

Q. Now were the reductions of the St. Clair observations carefully made?

A. They were carefully made.

Q. And as carefully made as those of the Niagara observations?

A. I believe they were.

Q. What percentage of error do you believe to exist in the reductions of the St. Clair observations, if any?

A. You mean how much error do I believe there might be in the final discharge of the St. Clair River?

Q. Due to the reductions alone; that is error in your office work here, in calculating, using the slide rule or whatever apparatus you used?

A. I believe that error is so slight as to be negligible, in comparison with the errors of observation.

Q. What percentage of error would be introduced due to error in gage reading

A. In what?

Q. As they were introduced into the computations?

A. I don't understand that question.

Q. (Question read as follows: "What percentage of error would be introduced due to error in gage reading"). You said individual gage readings might be .05 or .06 of a foot in error.

A. What I meant was that an individual reading of the gage did not represent the water level at that instant at that point within .05 or .06.

Q. But none of your measurements are tied up to a single gage reading, are they?

A. They are not.

Q. In the gage readings as they occurred in a series of 50 discharge measurements, what percentage of error would be due to them in your result as connecting the discharge with the gage elevation?

A. I think the percentage would be so small as to be negligible.

Q. Are there any other sources of error or inaccuracy in the St. Clair observations and discharges known to you, other than the ones which you have pointed out?

A. No.

Q. You say you graduated from the Massachusetts Institute of Technology, I believe?

A. Yes, sir.

Q. In 1906?

A. 1905.

2982

Q. And you were for about nine months with, what was the name of the concern? Who were you with before you came with the Lake Survey?

A. Directly before, I was at the Boston Tech, as Assistant Instructor.

Q. From whom did you receive instructions in the methods of operation in your stream gaging work?

A. Practically all my knowledge has been gained from my work on the Lake Survey, although I received in the Institute a brief course in stream gaging.

Q. From what particular individuals in the Lake Survey?

A. I have learned mostly from Mr. Shenehon and Mr. Moore.

Q. And you received no instruction from anyone except the persons in the Lake Survey?

A. No direct instruction, no.

Q. I presume you studied at some college did you?

A. As I say, I had a brief course in stream gaging in college.

Q. Did it cover the methods used by the Lake Survey

A. No, it took up current meter work in a small way in canals.

Q. What meter did you use?

A. Personally I used the Fteley Meter on one occasion, and I saw a Price Meter and a Haskell Meter operated.

Q. That was in connection with your college work?

A. Yes.

Q. Did you ever make any measurements of small streams, discharge measurements?

A. I assisted Mr. Moore in measuring three canals at Sault Ste. Marie, the two power canals at Niagara Falls, the rivers tributary to the St. Clair River.

Q. What one?

A. The Black, Bell and Pine.

Q. When was that done?

A. In 1910. I do not now recall any other.

Q. How extensive were the measurements of these small streams?

A. The measurements in the power canals were very extensive.

Q. I am speaking of the rivers or streams?

A. Just a very few measurements.

Q. Did you endeavor to determine an increment?

A. No.

Q. Did you ever observe with a current meter the velocities at points nearer together than .1 of the depth?

A. I don't now recall that I ever did.

In further answer to that previous question: We gaged the power canal of the International Paper Company at Niagara Falls.

Q. The gaging of these canals that you mentioned, that was done while you were with the Lake Survey?

A. Yes, under Mr. Moore's supervision.

Q. You used the Haskell Meter?

A. Haskell Meter, yes.

Q. Did you ever make a comparison of the coefficient of a vertical when points were observed at the one-fifteenth or one-twentieth depths, with that for .1 depth observations?

A. I don't recall that I ever did.

Q. You spoke of a weir. Will you just describe a weir, how it is used to measure water?

A. A weir is essentially a notch through which water is allowed to pass and spill over in a free overfall. Usually they have sharp edges on the upstream edge. They are frequently rectangular, sometimes trapezoidal, sometimes triangular. The head is variously measured by a gage placed at a suitable distance upstream from the crest of the weir.

Q. How and by whom have they been calibrated?

A. What weir do you mean?

Q. Any weirs?

A. They have been calibrated by Bazin, James B. Francis, Alphonse Fteley; I believe by Frederic P. Stearns and Mr. Gardner S. Williams and other notables whom I do not now recall.

Q. Have you ever measured water by means of a weir?

A. I can recall but one occasion, and that was during my instruction in the Massachusetts Institute.

Q. What were the dimensions of the weir, what was the head of the water and purpose of measurement?

A. I don't recall except that it was a small weir, and I believe it was in the tail water coming from a small turbine and that we were attempting to derive a value for the efficiency of the turbine at a certain speed.

Q. How large was the weir?

A. I could not say now, but it was a very small affair.

Q. Ten inches or ten feet?

A. Nearer ten inches.

Q. Then you never have compared the volume of water

measured by a Haskell Meter with the measurement of the same volume by any other device?

A. By the Price Meter.

Q. Give the particulars of that measurement?

A. I have used the Price Meter and the Haskell Meter side by side at Section Dry Dock in the St. Clair River.

Q. How closely did they agree?

A. They agreed very closely in calm water; not so well if there were waves on the surface of the river.

Q. How deeply were the current meters submerged?

A. At the Section Dry Dock, discharges were always measured with the meters at mid-depth.

Q. What was the difference between the Price and the Haskell Meter in the perturbed water that you speak of?

A. You mean when there were waves on the surface?

Q. Yes?

A. The divergence on one occasion was ten per cent.

Q. In your opinion, do you believe that the water was disturbed in the vicinity of the meter at half the depth?

A. The reason for that divergence was that a moderate swell was running on the river, and the catamaran was moving up and down somewhat. That motion is well known to cause the Price Meter to over register considerably.

Q. Have you made any other comparisons?

A. I made a few comparisons between the two meters on one of the still water rating bases.

Q. Have you made any comparison between the Haskell Meter and any other device for measuring water, the flow of water?

A. Not that I now recall.

Q. And you have never been present when any comparisons were made?

A. I can't think of any now.

Q. If in determining the mean velocity in a certain vertical two series of measurements were made, in each of which the velocities from surface to bottom were observed ten times, and in one series they were observed at the .1 depths, in the other at the one-twentieth depth which series in your opinion would give the more accurate determination of the ratio between the mean velocity in the vertical and the velocity at the .4 point?

A. I believe there would be practically no difference.

Q. Then in your opinion ten observations are as good as 20? Is that the result we are supposed to reach from your answer?

A. I don't believe I understood your question then. There were ten observations at each point, at one-twentieth depth in one case and at .1—oh, twice as many observations in the second case?

Q. Yes?

A. I wish to modify my statement. It seems to me that other conditions being equal, somewhat greater accuracy would be obtained in the second case.

Q. That is where it was observed at the one-twentieth depth?

A. Not because of observing at the one-twentieth depth, but because there were a good many more observations.

Q. How much better would you think it would be?

A. That would depend on various conditions. I believe that such relation can be obtained under good conditions in a large stream very accurately in the first case.

Mr. Hopkins: That is at .1 depths?

A. Ten observations each at each tenth of the depth.

Mr. Adcock: Q. Have you ever made any experiments in that connection?

A. I can't recall them.

Q. Did you ever make any current meter measurements on the St. Clair, Detroit, Niagara or St. Lawrence Rivers, to investigate the question as to whether or not the rate of travel of the crest of a rise of the lake coincided with the rate of travel of the increased discharge corresponding to that stage of the lake?

A. I never made any direct measurements of that matter.

Q. Do you know whether it does or not?

A. I have several reasons for believing that it does.

Q. State your reasons?

A. In the first place, it seems natural to me that a change in velocity should take place quickly with the change in slope.

In the second place, assuming that change in velocity did travel with the change in stage, the discharges in the Delta Sections of the St. Clair River were referred to Lake Huron and Lake St. Clair stages; and these results check almost exactly the results obtained by direct measurements at Section Gorge and Section Dry Dock.

In the third place such experiments as you state have been made, I understand, by Mr. Shenehon. I have seen some charts that he plotted from his results, and it seemed to me that those experiments proved it.

In the fourth place, Mr. Moore observed that very thing

on the Drainage Canal at Chicago, recently. In view of those considerations, I do believe that the change in velocity follows closely the change in stage.

Q. That is you mean that the full change of velocity would follow the change immediately?

A. I am not certain that the full change of velocity does, but I believe that by far the greater part of it does.

Q. Well, how immediately, how closely does it follow; how closely does it coincide with the crest?

A. As I recall Mr. Shenehon's experiments, there was no difference in time that could be scaled in the plots. In Mr. Moore's, the observations were such that when plotted, there seemed to be a slight lag of the velocity behind the stage, as I understand the plot. But within the error of observations apparently the full velocity or very nearly the full velocity change occurred within 30 minutes or so of the first break in the stage.

Q. That is you are referring to Mr. Moore's experiments?

A. To Mr. Moore's observations on the Chicago Drainage Canal.

Q. What about Mr. Shenehon's observations?

A. I don't know as I can state anything further about his than I have already stated.

Q. Do you know where Mr. Shenehon made his observations?

A. I understood they were made either at the bridge or at the Open Section on the Niagara River.

Q. How did he make it?

A. My understanding was that a meter was suspended at some depth of the river and allowed to run continuously for a long while, its registration being noted frequently and the corresponding velocity deduced.

Q. How would he know whether the full change of velocity had been reached, to correspond to the change of stage? Where else did he measure his velocity?

A. I am not thoroughly familiar with Mr. Shenehon's work, and I do not think I could state anything further in regard to it.

Q. What was the range of velocity at the Delta Sections, and at the Gorge and Dry Dock Sections?

A. I have here the mean velocities on each of those sections and the approximate maximum.

Q. Just give us that?

A. I could not give the range from maximum to minimum.

Q. From mean to maximum would do just as well; the mean and the approximate maximum?

A. At Section Gorge, the mean velocity was about 5.6, the maximum about 7. At Section Dry Dock, the mean was 3; maximum 4.4. Do you want that separately for the various—

Q. No, have you got it combined there?

A. The mean velocities for the six Delta Sections was in the neighborhood of 1.8 feet per second and the maximum velocity observed on any section was about 2.8.

Q. Then as I understand it Mr. Richmond, assuming that Lake Michigan should rise a foot suddenly, then as soon as the crest reached, say the Gorge Section, there would be a change in discharge at the Gorge Section to correspond to the change in stage immediately upon the crest reaching the Gorge, is that correct?

A. I believe that condition would take place within a few minutes.

Q. And that would be true on down the river?

A. As I understand your question, it would. I do not mean to say that the river would be in equilibrium, however.

Q. But you mean that the quantity of water flowing would correspond with the stage of lake?

A. I believe that the quantity of water passing any section on the river would depend on the stage at that section and the differential slope at any time.

Q. (Last question read) At a given point, at the time the crest reached that point as the result of the change in stage?

A. I do.

Q. In other words what we want to get at is whether the river is discharging, at the Gorge Section say, the amount of water which would correspond to the stage at the time the crest reaches the Gorge?

A. As far as Lake Huron is concerned, I believe it is, but the discharge at the Gorge depends partly on the stage downstream, and until that crest has traveled away down the river and the conditions have come to equilibrium, we would not find the discharge agreeing with the headwater and the back water in its proper relation.

Q. Assume the same conditions with reference to change of stage etc. on the Niagara River that we have assumed with reference to Lake Huron and the St. Clair River, and taking the point, for instance the International Bridge Section?

A. I believe the same thing that I have attempted to state

with respect to the St. Clair River prevails, but the back water cuts a much smaller figure on the Niagara River.

Q. Then you consider that in the case of the Niagara River it would not be necessary for it to reach a condition of equilibrium all the way through corresponding to the change of stage?

A. Not as necessary.

Q. It would have then some effect, you think?

A. A very small effect.

Adjourned to Thursday, February 19, 10:00 A. M.

Thursday, February 19, 1914,
10:00 o'clock A. M.

WALDEMAR S. RICHMOND testified further on cross-examination as follows:

Mr. Adcock: Q. Have you records showing the index velocity for each traverse of the verticals in the Split Section work; also water elevation during each traverse of the vertical, and copies of the plotted mean vertical curves in the Split Section?

A. I have in the records, I believe, the velocity at the index.

Q. For each traverse of the vertical?

A. Yes. That is in the note books. I have no gage readings that I recall during the measurement of verticals, but I have plots of the mean vertical for each station.

Q. Would you furnish us with a memorandum table showing the index velocity for each traverse of the vertical, and copies of the plots of the curves?

A. I believe the office would be willing to furnish those, yes.

Mr. Adcock: I will ask that they be marked, when furnished, Richmond's Exhibit B, for Identification.

Q. Will you state how you placed the meter, say at the .7 or .6 depth in the depth of 60 feet on the Gorge Section work, in the coefficient work?

A. The meter was set at the .6 depth by paying out enough cable to lower the meter by the vertical amount necessary and also by the extra length required by the curve taken by the cable. That correction for extra length was derived from observations of deflection, as already stated.

Q. That is you used a table or formula?

A. That was tabulated and we used a table.

Q. What table was used in that?

A. Those corrections were derived by Mr. Moore, and I believe are based on Mr. Shenehon's theory in regard to corrections. Mr. Moore derived the corrections and I simply used what he had derived.

Q. Have you a copy of the table?

A. The table I used was on a filing card and I do not know where it is now.

Q. That table is used in the office here, is it, in your work?

A. The table based on Mr. Shenehon's theory?

Q. Yes?

A. That is in his 1900 report, Army Engineers. But I used a table constructed presumably from that and the deflection angles by Mr. Moore, and written on an index card. I don't know where that card is.

Q. Was it a different table than the one which was used by Mr. Shenehon?

A. I don't know just how it did differ.

Q. Who made up the table that you used?

A. Mr. Moore made the table that was on the card.

Q. Go ahead and explain further, if you have any further explanation, as to the method by which you determined the position of the meter at the .7 depth?

A. I don't know that I can add anything further than that the proper length of cable was paid out in that manner.

Q. And according to this table that you have?

A. According to this table, which was compiled in 1908, and verified in 1909.

Q. What did that table show? Can you give us any idea of it further than you have stated?

A. As I recall, it gave a tabulation of corrections to be added for each different tenth of depth for each vertical and the straight proportionate depth for a given stage.

Q. Was it in feet?

A. Feet and tenths.

Q. Tenths of feet?

A. Yes.

Q. How near was the meter placed to the .7 or .6 depth in your coefficient work in deep water?

A. I have already stated that I believed vertically those positions were within .3 of a foot.

Q. That is at the .7 and .6 depth, in 60 feet of water?

A. I think they were within that.

Q. Well, your opinion is based entirely upon the method by which you did the work and the accuracy of this table, isn't it, as to the position of the meter?

A. My opinion is based on the fact that I know this table was satisfactory to me. It was based either on Mr. Shenehon's theory or Mr. Ray's, I am not positive which; and those two theories agree almost exactly in final results for any depths and deflections we have ever used.

Q. Assuming that that table is correct then, which you have not verified—

A. I did verify it and I believe I am sure.

Q. How did you verify it?

A. I know I was satisfied—I cannot recall the calculations I made—but I was satisfied that it was correct.

Q. What I am trying to get at is: Were you satisfied from your own calculations or experiments that you made, or were you satisfied from the fact that you believed that Mr. Shenehon and Mr. Ray or Mr. Moore, perhaps all of them, had the correct theory, and did their work correctly in making up this table, which was it?

A. From experiments, I don't know,—in other words I have never made any experiments to derive such corrections; but I have compared and studied the theories of Mr. Shenehon and Mr. Ray, one being based on the variation in velocity in the flowing water; the other being based on still water, assuming the velocity the same at every point of the wire.

Q. You have used that table then—

A. And I have used both theories and have found that within the limits of depths and deflection angles that I have used, those two theories gave practically the same correction.

Q. Does that table take into consideration the fact that an A meter at the same position on the table as a B meter, and at the same depth in practically the same velocity causes the deflection to change from 7 degrees to 12 degrees?

A. I do not think any different correction was applied to the A meter than the B, but as I recall it the A meter was used at the index only, where the correction in any event would be a very small amount. On the vertical and in the deeper depths, I believe the B meter only was used.

Q. Then there was no method by which you could deter-

mine the direction of the meter at the deeper depths; that is if you used the B meter in your coefficient work?

A. No.

Q. Or the direction of the current at the deeper depths in the position of the meter at the .7, .6 or .9 depths?

A. No determination was made at the deeper depths.

Q. Do you know whether Mr. Shenehon's table was made up on the assumption that the horizontal force acting on the meter had no effect?

A. I understand Mr. Shenehon's table was based on that, but Mr. Ray's was based on the opposite assumption, and the two theories give almost identical corrections.

Q. Do you know whether Mr. Shenehon's table is used outside of the Lake Survey work?

A. I don't know.

Q. Am I correct in understanding that your conclusion, as you stated yesterday, as to the coincidence of the discharge in crest due to a given change of lake elevation is based mainly on the results of Mr. Moore's work on the Drainage Canal in December last?

A. It is also based on Mr. Shenehon's experiments as I know them; and it is based on what seems to me common sense, that nothing could intervene but the inertia of the water, and that change in inertia can be accomplished by the forces acting, in a very few minutes.

Q. What weight do you give to Mr. Moore's observations, in reaching your conclusions?

A. I give them great weight.

Q. Equal weight with Shenehon?

A. I give them more weight, because I know them better.

Q. Do you consider the results obtained on the Drainage Canal applicable to the cases of the St. Clair, Niagara, St. Lawrence and Detroit Rivers in this particular, with reference to the lag and the discharge being coincident with the travel of the crest, etc.?

A. I believe they are sufficiently applicable for the discussion in hand.

Q. In Mr. Shenehon's observations on the Niagara River in this connection, did he measure simultaneously the discharge at two places in the river?

A. I don't think he did but I am not positive.

Q. You think he did?

A. I don't think he did.

Q. Assuming that he did not measure the discharge at two

places simultaneously, do you think he could be sure that the discharge at one place coincided with that of another at any particular time?

A. Within reasonable limits, yes, because rivers flow under definite laws, and when the velocity at one point in a section is affected, there is in general a corresponding effect at every other point in the section.

Q. That is you mean in the discharge or in the elevation?

A. In both, if it is due to the effect of change in the lake stage.

Q. Within what per cent. of accuracy?

A. I should say closer than 10 per cent. The best data I have on that that I now recall is in regard to measurements in the power canal of the Niagara Falls Power Company, where discharge was observed at perhaps 10 stations, and another meter was run simultaneously at one point in the canal further upstream. A general coefficient was derived for the single meter, and by means of it the discharge could be determined within a few per cent., for any condition of operation that was observed.

Q. Did you have the discharge at two points determined simultaneously?

A. Determined at a general index meter not on that section; and determined in the standard manner by observations at the index points on the section.

Q. Within what percentage of accuracy could it be determined in that way?

A. I don't recall the figures exactly, but I believe that no single discharge differed more than six or eight per cent.

Q. Do you think the single meter indicated the discharge within six or eight per cent?

A. That is my recollection. It may have been even better.

Q. How far apart were these two sections?

A. The single meter was at the upper end of the canal where the section was the same depth and perhaps twice as wide, and I think possibly 300 feet upstream from the section measured.

Q. What was the change of elevation between the two stations 300 feet apart, as you stated?

A. I have not much idea. It was considerably less than half a foot.

Q. How wide was the canal?

A. At the section, as I recollect, it was about 180 feet wide.

Q. And where the single meter was, how wide was it?

A. Roughly I should say about twice as wide. I am not very certain about that.

Q. What weight do you give to those observations in reaching the conclusion which you have stated?

A. I give that simply as an illustration of my point that rivers and canals flow according to definite laws, and if a change is noted at one point in a section or in a nearby section, we may reasonably expect a corresponding change in other points of the section.

Mr. Hopkins: You mean over a definite period of time?

A. Yes, within a brief period of time.

Mr. Adcock: Q. Don't you think these two sections that you speak of on the power canal were too close together to give accurate results?

A. No, there was another condition entering. Between the upper meter, which was the solitary meter, and the section, the intake of the International Paper Company branches out from one side, which would seem to me to introduce an element of uncertainty, so that the conditions there might be even worse than between points on the same section in a river.

Q. Have you any data in the office here which shows the results obtained there?

A. I believe that data must be here. I am not particularly familiar with it.

Q. Would you be willing to furnish it to us at the proper time, or when you can find it?

A. Mr. Moore is more familiar with that than I am. I believe I can furnish it.

Q. What has been the effect of the Gut Dam on the level of Lake Ontario?

A. The presence of the Gut Dam has caused a rise in surface of Lake Ontario.

Q. About how much?

A. I believe between .3 and .4 of a foot.

Q. For a given discharge of the St. Lawrence River under present conditions, how much higher would Lake Ontario be than for the same discharge before the construction of the Gut Dam?

A. By my own computations, practically .32 of a foot.

Q. Do you consider that the sounding work, coefficient

work, the discharge observations, meter ratings, gage readings were as accurately done in the work upon the St. Lawrence River as upon the Niagara River at the Bridge Section?

A. I believe that the observations were all as accurately made, but that certain conditions entered which made the final results considerably more discrepant.

Q. What are those conditions?

A. In my opinion one condition is that the bottom of the river is much rougher, making it impossible to determine the cross section quite as accurately.

Another condition is that the river is gorged just below the section; the velocities are accelerating very rapidly past the section, and it becomes of much greater importance to observe velocities exactly in the same section in which soundings are taken; and I believe that that was not always absolutely done. That is I believe velocities were sometimes measured a little upstream or a little down stream from the section sounded, and because of the rapidly accelerating velocities, there was a residual error in the discharge.

Q. That latter difficulty was not on account of the inaccuracy of the work done by the men on that section, but because of the conditions?

A. Because of more difficult conditions.

Q. These that you mentioned?

A. And which were not fully realized, perhaps, at first.

Q. Then in your opinion this section, Three Point Section, was not a good section to measure?

A. I would not say that. It was a more difficult section in some respects to measure.

Q. Then the results were not such as might have been obtained on other sections?

Mr. Hopkins: In the same river?

Mr. Adcock: In the same river.

A. I doubt if a better section could have been chosen in the St. Lawrence River.

Q. Have you made any survey of the river to determine that question?

A. I have never made any surveys, but I have made more or less of a reconnoissance of the river and have studied the charts very closely; and I have decided that it was a very difficult matter to chose an excellent section, and that probably no better section for gaging with Haskell meters could have been selected than Section Three Point.

Q. I presume the choice of a section, etc., depends largely

upon the judgment of the person who is making it, doesn't it?

A. Largely, yes.

Q. And the value of the work or the results obtained depend upon his judgment?

A. To some extent, of course.

Q. What is the percentage of error in the work on the St. Lawrence River due to the rough bottom?

A. That is not known, because the same determination of cross section has been used in all the computations.

Q. So you could not give any percentage of error, as you have in other instances?

A. I re-determined the area of Section Three Point and Mr. Moore re-determined it. It was first determined by Mr. Shenehon. In my opinion, we all three sounded slightly different sections, not very different. The outside discrepancy was less than half of 1 per cent. in the three measurements.

Q. You all, I presume, intended to sound the same section?

A. What is that?

Q. You all intended to sound the same section, didn't you?

A. I don't think so if I understand your question. The method of working used by Mr. Shenehon, as I understand it, was to keep the steering wheel of the catamaran on section, and he suspended his sounding wire from an overhang on a pulley somewhat forward of the steering wheel; and I believe he suspended one of his meters from the same wheel.

Q. At the same time?

A. Later, bringing the meters and sounding weight except for the difference due to deflection in the same section.

Mr. Moore did the same thing, but I believe that his overhang was nearer the steering wheel; that is down stream from that used by Mr. Shenehon, bringing his section a little down stream where the section is perhaps a little smaller and the velocities a little greater.

In my work, I sounded exactly in the plane of the section, but in measuring velocities I kept my steering wheel on the section and allowed the meters to be suspended somewhat upstream. But in all the reductions, the cross section determined by Mr. Shenehon has been used.

Q. Is there any record in the office showing how these sounding wires were suspended, as you have mentioned, or do you know this from conversation with Mr. Shenehon and Mr. Moore, as to the method they used?

A. There is full record about my own work, and fairly complete record about Mr. Moore's; less complete about Mr.

Shenehon's. I have gained some of my knowledge of the conditions during his work from conversation with him and his assistants.

Q. Then Mr. Moore's gagings and your gagings have all been referred to a different section than the one that you measured?

A. Not that at all. My meters were in every case suspended, as nearly as I can find out, in almost exactly the section sounded by Mr. Shenehon; and Mr. Shenehon suspended his meters in that same section sounded in 1900. It is my personal opinion that in 1901, Mr. Shenehon's meters were suspended a little further down stream, and that Mr. Moore's meters were suspended in about the same position.

Q. What was the mean velocity on the St. Lawrence at this section?

A. Mean velocity of Section Three Point is about 4½ feet a second.

Q. What is the depth? What is the greatest depth?

A. Maximum depth, 60 feet.

Q. How many stations or panels did that cover?

A. There are 17 panels.

Q. In how many was the depth 60 feet approximately?

A. Vertical 9 was about 60 feet deep.

Q. That was at high water, wasn't it, high elevation of the lake?

A. It is not high water as I recall. That is for a stage of about 226 I believe—no, 230; that is for stage 230 at the section.

Q. What was the minimum velocity and the maximum velocity in that vertical? What was the number of that vertical?

A. Number 9 is the deep vertical.

Q. What was the minimum and maximum velocity that you observed at the index point .4 depth?

A. I could not say that without about an hour's search in the books. I could give the mean.

Q. Have you got the maximum and the mean?

A. The mean index velocity is about 5.2 per second.

Q. Have you a record there of the maximum?

A. I haven't here, no.

Q. Do you remember approximately what it was?

A. It would vary about in proportion to the variation between high and low discharge, roughly.

Q. Could you ascertain that for us from the records, without too much trouble?

A. I could look that up, yes. The maximum and minimum?

Q. Yes?

A. Index velocity that has been observed on vertical 9.

Q. Yes. When did you do your work on the St. Lawrence River?

A. I had charge of the work there in 1911 and 1913; and I worked there under Mr. Moore in 1908.

Q. How many discharge measurements did you make, approximately?

A. Mr. Moore made 26 in 1908. I made 62 in 1911 and 35 in 1913.

Q. Have you tables showing the index velocities and the percentage velocities in each of the 17 verticals in Three Point Section that you measured the same as you had and furnished, and the same as were marked Richmond's Exhibit A, for Identification, in connection with the work on the Split Section on the Niagara River?

A. You are speaking now of vertical curves?

Q. Yes, of your own observation. (Question read.)

A. I re-determined coefficients on 6 of the 17 verticals and I have such computations for that.

Q. I presume in connection with that, in connection with your sounding work, you have the records showing the inclination of the sounding wire and the inclination of the meter wires in those different verticals?

A. Those records are in the office.

Q. They are in note book form. On what verticals did you re-determine the coefficient?

A. Verticals, 7, 8, 9, 10, 11 and 15.

Q. Those were where the water was the deepest?

A. With the exception of 15. Those verticals represented 56 per cent. of the discharge.

Mr. Adcock: That is all.

Saturday, February 21, 2:45 P. M.

Re-direct Examination by Mr. Hopkins.

Q. Mr. Richmond, in speaking of the Oakfield Section of the Niagara in vertical 8, you said that the coefficient of that vertical might have a possible error of 1 per cent. On what side might that error be?

A. I believe I stated that I thought it might be either way.

Q. And what effect would such an error as that have upon your total coefficient work, in your opinion?

A. I stated that I believed the weighted mean coefficient for all the work to be within 1/2 of 1 per cent.

Q. That opinion is not changed?

A. No.

Q. What were the surface conditions at that section, as well as the Wickwire Section, during the soundings?

A. The surface was smooth on the days when soundings were taken.

Q. Did you make any correction for the direction of the current?

A. Yes.

Q. Just tell us how?

A. The direction of the current was determined by running rod floats which were 14 feet long, and locating them by two transits on shore. The paths of these floats were plotted, and the amount by which the stream lines diverged from the perpendicular to the section scaled from the plot was used as representing the current deflection for the various panels.

Q. Did you, and would you use an arithmetical method of computing mean ordinates or coefficients, as suggested by Mr. Adcock in his questions on your cross-examination?

A. I did not, and I would not.

Q. Mr. Richmond, where your panels were 200 feet wide and you measured velocity at one point in the panel, what error do you think would come into your total velocity work when not measuring in between the stations?

A. I considered that the error would be smaller than I need consider in making those observations.

Q. That is on the total volume of flow?

A. Yes.

Q. What is that based upon, in your opinion?

A. That is based upon my general knowledge and experience in regard to streams. Where we have a smooth section if we know the velocity at two points 100 feet apart near the center of the stream, we know that there is no wide deviation from that at a point in between.

Q. Suppose there were an obstruction which interfered with the velocity at some point there, could you and would you in such measurements as you have made in, say the Niagara River, detect it?

A. If there was an obstruction which would cause a detrimental effect on the measurements, I believe it would be detected by the measurements at points arranged in that manner in a stream.

Q. Would your soundings help tell it?

A. Of course the soundings would help very materially.

Q. Would the surface indications help to tell you of such a perturbance?

A. Yes, they would help.

Q. And if you find such a point of perturbation, do you make measurements at that point?

A. In case such a point was found, special care would be taken and extra measurements made, to be sure the proper corrections would be applied.

Q. Now referring to deflections of cable wire, did you make any corrections for that, so as to bring your meter to the proper elevation?

A. Yes, as already stated in cross-examination, I believe, the corrections which I considered proper were always made.

Q. In an ordinary river, where the flow is comparatively even, would it make any difference in your velocity measurements if your meter were a little bit downstream from the section?

A. I do not consider it would make any practical difference.

Q. What conditions would make a different result?

A. If we had a section at a point in the stream where velocities were rapidly accelerating or retarding, it would be important to keep the meter exactly in the proper plane.

Q. I believe you said that you thought there was an acceleration in the St. Lawrence below the section?

A. At Section Three Point, yes.

Q. To what extent do you think this would affect your velocity work at that place?

A. I have only a few experiments on that, but I am now

of the opinion that that difference is sufficient to account for the discrepancies which have been noted among various measurements at that section.

Q. Were there any such conditions of acceleration or retardation in the other rivers besides the St. Lawrence, at the sections where you made measurements?

A. At all the other sections there were not such conditions as at Section Three Point.

Q. In your cross-examination, in stating certain degrees of deflection at certain points in the St. Clair River of the cables suspending the meter, you gave some testimony as to degrees of deflection which were changing from 7 to 11 or some other figures. From whose notes were you testifying as to that?

A. I was testifying from Mr. Moore's record.

Q. Have you found out anything further as to whether they did indicate what you said they did?

A. Mr. Moore has informed me that I did not understand those figures.

Q. Do you wish to take out or change that part of your cross-examination based upon Mr. Moore's notes?

A. The two values that I gave as varying from, for instance perhaps 7 to 11 degrees, seem to have been a record of computations by Mr. Moore rather than observations.

Q. Those inclusive values then were not actual measurements, so far as you know?

A. That is the information Mr. Moore has given me.

Mr. Adcock: You would better state just what figures it was that you mistook in these note books.

Mr. Hopkins: Q. Just what figures were they, designate them. You mean the two inclusive figures, 7 to 11, and another one?

A. There were two figures giving inclusive deflections. One as I recall was 7 to 11 degrees, and the other I believe was 9 to 14.

Q. You want to withdraw those two?

A. Yes, I apparently did not understand those figures.

Mr. Adcock: We might just as well clear that up as we go along. (Q.) What was the true record of the deflection?

A. Apparently there was not a true record. Mr. Moore states that that was a record which he calls a computation and really not an observation. They were not my records and I could not state—

Q. A computation of what deflection?

A. It was the deflection of the meter cable when the meter was suspended at the index points on a certain vertical at Section Gorge.

Q. But there was no observation of it made, no actual observation made, or was it merely a calculation as to what the deflection ought to be?

A. As I understood from Mr. Moore, it was a record which to his mind represented the outside deflections he had observed at various times at that point, but I could not clear it up any further than that.

Q. In other words, ranging over a number of immersions of the meter at the .4 depth at that point, there had been a variation of deflection from 7 to 11 or 9 to 14 degrees, is that the proposition?

A. That is the idea I got from it.

Mr. Hopkins: Q. In your cross-examination, you were asked if you thought that the measurement of the discharge in the St. Clair River was as accurate as that of the Niagara. How about the increment of the St. Clair, in comparison with the Niagara?

A. I do not believe the increment has been derived as accurately as that for the Niagara River.

Q. Why?

A. Because the conditions from which it must be derived are much more difficult. We have on Lake Huron an outside range of stage of about 2.1 feet for all the observations ever made. A similar range on Lake St. Clair, and for any given stage on Lake Huron, only a very small fluctuation on Lake St. Clair, making it exceedingly difficult to separate the back water effect from the head water effect and derive any increment.

Q. What is your opinion as to the possible error in the increment as derived by the Lake Survey of the St. Clair River?

A. I would not want to say we knew the actual increment closer than 15 per cent. either way.

Q. You think that might be either way?

A. Yes.

Q. Did you ever make any tests of meters in rough water, the Haskell and Price meters?

A. I used the Haskell and Price meters side by side at Section Dry Dock in measuring certain discharges in 1909.

Q. Under what conditions?

A. Under favorable conditions for some measurements, and under conditions of wave motion on the river for others.

Q. Tell us what were the results of those tests?

A. When there was wave motion, the results by the two meters differed, and on the day of the greatest wave motion the results were most discrepant, being about ten per cent. apart.

The results by the Haskell Meter, however, plotted close to the line of discharge law in every case; the error apparently being in the Price meter, which is known to over register under such conditions.

Re-cross Examination by Mr. Adcock.

Q. What portion of the cross section at Oakfield and Wickwire was occupied by the meters in making a single discharge measurement?

A. The meters were run at the index points only in making those measurements, there being 11 index points on Section Oakfield and 10 on Section Wickwire.

Q. What proportion of the cross section was actually occupied by the meter?

A. You mean the cross sectional area of the meter wheel in proportion to the section itself?

Q. Yes?

A. Almost infinitesimal.

Q. Did you ever in your gaging find a point of perturbation lying between verticals as laid out by you on your gaging section which you measured?

A. I recall one instance in a power canal.

Q. You never noticed any on the rivers, though?

A. I do not recall any.

Mr. Adcock: That is all.

BAMLET KENT, a witness called in rebuttal on behalf of the Government, was first duly sworn and testified as follows:

Direct Examination by Mr. Hopkins.

Q. State your full name?
A. Bamlet Kent.
Q. Where do you live?
A. In Detroit.
Q. You are an engineer, are you?
A. Yes, sir.
Q. In what service?
A. In the Engineer Service of the United States.
Q. What was your education and training Mr. Kent?
A. My training was at the Michigan College of Mines.
Q. What experience have you had in your work?
A. About 19 years, between 18 and 19 years.
Q. Have you been that long with the Government?
A. About 18 years with the Government.
Q. What has been the nature of your work with the Government?
A. Triangulation work, taking soundings, looking after dredging, and looking after construction work.
Q. Have you done much dredging work in the Great Lakes and the rivers connecting them?
A. I have, yes, sir. Looked after it.
Q. In what lakes and rivers and places have you done such work?
A. In Portage Lake, Portage Lake Canal, Portage Lake River, St. Clair River, foot of Lake Huron; and the head of the Detroit River.
Q. Referring to some work in the Rouge River, just what did you do there?
A. We have removed there altogether, since the Government has taken charge of it, about 820,000 yards.
Q. That is cubic yards of earth?
A. Cubic yards.
Q. Where did you deposit that?
A. Deposited it in the Detroit River in 30 feet or over, in front of the mouth and below the mouth of Rouge River.
Q. Are you familiar with the dredging that has been done by the United States Government in the St. Clair River?
A. Yes, sir.

Q. Will you just tell us what has been done, either by you or under your supervision?

A. The Government has removed from the Black River at Port Huron 443,034 yards.

Q. When you speak of yards you mean cubic yards?

A. Cubic yards. This was taken out of the Black River and deposited about a mile below the mouth of Black River in St. Clair River. The Government removed 82,978 cubic yards from Pine River and deposited it almost directly in front of the mouth of the river in 30 feet or over of water. From the Bell River at Marine City, the Government removed 168,326 cubic yards and deposited that in 30 feet or over, directly in front of and a little below the mouth of the river.

At the mouth of Black River, the Government removed from close to the docks and along in front of the docks 353,484 cubic yards, which also was deposited about a mile below the mouth of Black River in about 30 feet or over of water.

Opposite Port Huron, on the middle ground, the Government removed 231,498 cubic yards, which also was deposited below, about a mile below the mouth of the Black River.

The Government removed from the vicinity of Stag Island about 219,000 cubic yards and about 106,000 cubic yards from various other shoals, such as opposite St. Clair, opposite Marine City and Squirrel Island. This material was all dumped in the St. Clair River.

Q. Any work in Lake St. Clair?

A. There was removed in Lake St. Clair at the canal by hydraulic dredge 2,044,801 cubic yards.

Mr. Adcock: Where was that placed?

A. That was placed to the east of the St. Clair Flats Canal in Lake St. Clair—to the west of St. Clair Flats Canal in Lake St. Slair. Besides that, there was 1,024,540 cubic yards removed by dipper dredges. That was deposited in Lake St. Clair. That was deposited in 14 feet of water or thereabouts east of the St. Clair Flats Canal.

In Lake St. Clair at the lower end, and at Grosse Point Channel, there was removed 5,664,263 yards.

Mr. Hopkins: Q. Where was that?

A. That was taken out of Lake St. Clair and deposited in Lake St. Clair.

Mr. Adcock: Right near the place?

A. That was deposited east of the channel along Lake St. Clair, the big bulk of it being at the Grosse Point dumping grounds.

Q. Was that by hydraulic dredge?

A. No, that was dipper dredge.

Mr. Hopkins: Mr. Kent, the earth deposited in Lake St. Clair itself, does that have any effect upon the flow from Lake Huron to Lake Erie?

A. I hardly think it would have; if so it would be very small.

Q. As the result of this work by the Government, what has been the effect upon the navigation channel, with reference to whether it has increased the depth or width and so on?

A. It has increased the width and increased the depth.

Q. What is the depth throughout the channel?

A. There is practically a navigable channel of about 21 feet.

Mr. Adcock: That is through Lake St. Clair?

A. Through Lake St. Clair.

Mr. Hopkins: How about the river?

A. Probably a maximum draft of about 22 feet.

Q. Through the river?

A. Yes.

Q. What was the navigable capacity before this Government work was done?

A. Before any Government work was done, about 9 feet I should judge.

Q. When was that?

A. I could not say, preceding 1860.

Q. Do you know the intermediate stages of the improvement of that channel?

A. I know them but I have not got the data in my mind.

Q. Now what has been the effect of depositing this earth in the St. Clair River?

A. There has been more material deposited in the St. Clair River from the rivers than has been taken out of the river.

Q. In your opinion, has this work of the Government had any effect upon the levels of Lake Huron?

A. I believe it has had none whatever as the material was all dumped—or not all dumped but the bulk of the material was dumped pretty much in one place in the cross section of the river, tending to shoal the entire cross section of the river below where the shoals were removed.

Q. In that way compensated for the dredging in other parts?

A. Yes, sir.

Q. Was it in Lake St. Clair or the river itself that they changed the navigable capacity from 9 feet to 21 feet?

A. It was in Lake St. Clair.

Q. In the approach to what channel was that?

A. From Lake St. Clair to the St. Clair River, through the old channel?

Q. Is that known as the South Channel?

A. That would be the South Channel.

Q. How many channels are there?

A. There are at present 3 main channels.

Mr. Adcock: That is in Lake St. Clair itself?

A. Distributaries of the St. Clair River.

Mr. Hopkins: Now what do you know of ice conditions in the St. Clair River?

A. Nearly every year, whether the river freezes over solid or not, if there is floating ice, invariably there are ice jams that form in the St. Clair River in the vicinity of Russell Island, from that above.

Q. That is there are ice jams from Russell Island on up?

A. Up.

Q. How about an open winter like this one?

A. Well, an open winter, ice jams take place just the same. Ever this year the small quantity of ice we have had, we have had one jam there this year, a short distance above Roberts Landing.

Q. Does that still exist?

A. I believe not. I believe that went out a short time ago.

Q. Was that a big jam or not?

A. It was a jam such that it brought the water up pretty close to the railroad track and also flooded a good deal of the low land above it; that is the main current was blocked, or at the middle ground at Port Huron.

Q. What effect did that have upon the flow below the jam?

A. It diminishes the flow.

Q. In the river?

A. It diminishes the flow in the river.

Q. A little more particularly about how much would you say?

A. At times, the jam is such that instead of having a current of upwards of five miles at the gorge between Ft. Gratiot and Point Edward, the current is practically not noticeable, the water being dammed back to such an extent that it is practically slack water.

Q. About how much of the time in the course of a year is the flow of the St. Clair retarded by ice?

A. I should judge that in average years the current is retarded at least about four months, between three and four months taking the average season; about three months say.

Q. Now does the river freeze over?

A. It does, the entire length.

Q. What effect does that have upon the flow?

A. It retards it and diminishes it, both.

Q. Seriously?

A. It does.

Mr. Hopkins: That is all.

Cross-examination reserved.

Adjourned subject to notice.

BAMLET KENT, recalled for further examination testified as follows:

Cross-Examination by Mr. Adcock.

Q. Is the deposit of material in 30 feet of water in the St. Clair River to a depth of one or two feet considered an obstruction to navigation?

A. No, sir.

Q. If a channel were built so that the water remained at all times not less than 30 feet deep, at all points, where you had that depth previous to the filling, would that constitute an obstruction to navigation?

A. All parts less than 30 feet filled?

Q. Yes?

A. No, it would not be.

Q. You testified with reference to certain excavation work that was being done in the St. Clair River and in Lake St. Clair. Who determined where the material that was excavated should be done?

A. The Engineer Officer in charge.

Q. The Officer in charge?

A. Yes.

Q. Upon whose recommendation?

A. Well, the Engineer Officer in charge is the army officer that is in charge of the District; the District Engineer decides.

Q. Do you know who it was?

A. It depends on what officer was here when the work was being performed.

Q. And who recommended it?

A. He himself chose that arbitrarily, the army officer?

Q. The army officer. Didn't he have anyone working under him who made recommendations?

A. He gave instructions to the inspector of engineers under him, and his instructions were carried out.

Q. Was the material dumped usually near where it was excavated?

A. Depending on whether the dumping ground had been assigned for the material near to the work or not. It depended on that.

Q. Was the dumping ground assigned usually near the excavated area?

A. If there was deep water, or if there were places away from the channel, it was assigned near where the work was.

Q. Did you personally have anything to do with the determination of where the material should be dumped?

A. Nothing, except following the orders of the Engineer Officer in charge.

Q. Do you know what investigations or calculations he made to determine the spoil area?

A. He took it from the sheet of soundings showing the depths, that was what decided where the dumping was to be done, where the soundings showed.

Q. In the past ten years, on how many occasions have you known ice jams to form in either the St. Clair or Detroit Rivers, or both of them?

A. I have known three definite ice jams; one during the week of February 8th; how long preceding that I don't know, but it was there on February 8, and for the next eight or ten days, 1904. It was there eight or ten days after February 8, 1904.

In February, 1909, there was another; and I think the latter part of January, 1911. That jam lasted for a considerable length of time, probably two or three months.

Q. Was that on the St. Clair River?

A. On the St. Clair River.

Q. Where?

A. The jam took place from Russell Island to Roberts Landing, or a little above.

Q. Was there any in the Detroit River?

A. That I could not say.

Q. How long did these ice jams last, that you mention in the St. Clair River? Take the first one that you mentioned?

A. I don't know exactly the length of time. I happened to see them at different times. From the gage readings at the time I should judge that the one in 1911 probably lasted between two and three months, about three months I should judge. The one in 1904, I know was solid for at least a month, but whether the full maximum stoppage of the water took place for that length of time I do not know, but I know it lasted upwards of that time.

The one in 1909, I believe lasted in the neighborhood of about a month, somewheres about that time.

Q. How long have you been connected with the St. Clair River, in your work?

A. Since 1903, April, 1903.

Q. Did you make any reports with reference to the condition of the ice?

A. Nothing but verbally except the one in 1904. And I gave them the thickness of the ice below Russell Island to about three miles out in St. Clair.

Q. How thick was it, do you remember?

A. The thickest we found was 44 inches. The average was somewheres in the neighborhood of about 32.

Q. Did you have any instruction from your superior officer as to making observations of this kind?

A. I was taking soundings for the new St. Clair Flats Canal, and consequently I was taking several hundred soundings a day with the men.

Q. Making the report with reference to the ice conditions there was incidental to your work in making those soundings?

A. We did give the depth of ice in each day's report, the depth through which we were boring holes.

Q. Is there anyone else here in the service who was detailed to make reports as to ice conditions in different years?

A. I believe not.

Q. Well, these statements then, with reference to the ice conditions are the result of simply casual observations that you made?

A In 1904, we were making a survey for the new St. Clair Flats Canal; and on February 8, I believe it was, Pere Marquette Ferry Number 14, left Detroit for Port Huron. When she struck the first jam immediately below Russell Island, she grounded on ice; there was ice underneath her all around. She had trouble in backing away, and finally did work her way

through. She again grounded above Algonac about two miles, on ice, and more or less ice underneath her until she got to Roberts Landing.

Q. Well, these observations with reference to ice conditions which you mentioned were the result of the facts that you happened to see, in connection with other work, isn't that true?

A. Yes, sir.

Q. When the ice jam breaks, is the flow greater or less than before it was formed?

A. It is greater.

Q. Does this increased flow tend to compensate for the reduced discharge during the existence of the jam, in your opinion?

A. What was the question again?

Q. (Question read).

A. The increased flow would take place immediately when the jam was broke but would not be increased except the head would increase. It would only increase the amount which the head was increased. It would increase for the time being. When the jam broke, that jam going out would cause the water to flow faster until it gets its natural slope again.

Q. You stated in your direct examination that during the time these jams existed there was no current in the gorge in the St. Clair River?

A. Didn't I state no visible current; didn't I say visible current in my original testimony?

Q. I understood you to say there was practically no current?

A. I believe I said practically no visible current; I believe that is what I said, because there is a current there but it is not visible to the eye, because it takes considerable current for you to notice it as you casually look over water. There is a current but it is practically not visible.

Q. For how long a time did that condition which you mentioned with reference to the current exist?

A. That I don't know.

Q. You didn't make any observations with reference to that?

A. No, sir.

Q. You just noticed it as you came in contact with the jam, as you have mentioned?

A Yes, sir.

Q. Was that each jam that you mentioned or just on one occasion that you noticed it?

A. I have only noticed it on one occasion in regard to the current. The other is hearsay in regard to the current, hearsay from other men.

Q. There was water flowing through the river, wasn't there, at that time?

A. There certainly must have been some, yes.

Q. In the event the discharge of the St. Clair River is reduced by ice, will that reduce the discharge of the Detroit River, assuming that there is no ice jam in the Detroit River at that time?

A. In the St. Clair River, you say there is?

Q. Yes, if there is a jam in the St. Clair River and there is no jam in the Detroit River, and the jam in the St. Clair River reduces the discharge of the St. Clair River, will the Detroit River discharge be reduced?

A. It certainly will if Lake St. Clair is reduced; as soon as the head is reduced, the discharge will be reduced.

Q. Has there been any scouring in the channels in Lake St. Clair?

A. In parts of it there has been considerable.

Q. That is the channels are deeper than they were when originally excavated, is that right?

A. Yes, sir.

Q. And wider also?

A. In places, yes.

Q. Do you know to what extent the scour has taken place and the channel has been widened in Lake St. Clair?

A In about the center of Lake St. Clair, the channel probably is about 800 feet wider than it was formerly.

Q. How much deeper?

A. That will vary from practically nothing on the sides, to between one and two feet.

Q. In the center?

A. Well, yes, in the center of the channel.

Q. And that exists all the way through these channels?

A. No, wherever there is much sand, there has been no scouring, wherever there has been sand. The scouring has taken place only where there has been clay.

Q. What causes this condition of scouring?

A. By deep draft boats causing the milky substance from the clay to go into suspension, and it is carried away by the current.

Re-direct Examination by Mr. Hopkins.

Q. These ice jams that you speak of in 1909 and 1911, are all the jams that you yourself saw?

A. Well, I saw each of those jams.

Q. You do not mean to say those were the only jams that were?

A. Oh, no, not by any means. They happen to be the ones where I was there personally and saw them myself.

Q. Wasn't there one there this year, or hasn't there been one?

A. There was but I didn't see that. That was hearsay.

Q. How about other years?

A. I believe there have been jams every year that there has been any ice whatever; I believe there have been jams.

Q. At least until this month, this was considered an open year, wasn't it?

A. Yes, it was considered a very open year until the beginning of this month.

Q. And when was this jam that you speak of?

A. The jam took place I believe either the latter part of December or early in January. I believe it was in January, come to think of it, in January.

Q. Now after the jam breaks and this increased flow takes place immediately, it lasts about how long?

A. Until the river assumes its regular slope again.

Q. That is until Lake St. Clair fills up?

A. Yes, sir.

Q. About how long do you think that would take?

A. Well, I should think that Lake St. Clair would adjust itself in the course of probably a week or ten days.

Q. Now this scour, you say that the wheels of the vessels stir up the fine clay, and it is in suspension. As a matter of fact doesn't most of that float out to the sides?

A. It deposits in other parts of the lake undoubtedly.

Q. It is not a wash so much as it is a stirring up of the—

A. No, it is purely a stirring up by the boats. There is no current to cause a scouring.

Q. When you spoke of dumping of one or two feet in 30 feet of water, that that did not interfere with navigation, you meant navigation as it is at the present time?

A. Yes, sir.

Q. Do you know to what depth the Welland Canal is being built

A. 30 feet.

Mr. Hopkins: That is all.

Recess to 2:15 P. M.

After Recess, 2:15 P. M.
February 17, 1914.

WALDEMAR S. RICHMOND, resumed the stand and further testified as follows:

Cross-Examination by Mr. Adcock.

Q. You made some measurements of the flow of the Niagara River in 1913, did you not?
A. Yes.
Q. That was at what is called the Split Section?
A. That has been called the Split Section.
Q. It has been called that in the testimony so far?
A. Yes.
Q. What is the reason you called it the Split Section?
A. I presume because it is in two parts, one on each side of Grand Island.
Q. The river is divided at that point?
A. The river is divided at the head of Grand Island.
Q. About how far is that from the International Bridge?
A. The sections, or the head of Grand Island?
Q. No, the section which you measured, the gaging section?
A. They are 4 3/4 miles from the foot of Squaw Island.
Q. I asked you how far it was from there to the International Bridge Section?
A. That would be between 5 and 5 1/2 miles.
Q. When did you do your work there, what time of the year?
A. It was in July and August.
Q. From whom did you receive your instructions?
A. From the officers of the Lake Survey, mostly from—
Q. Mr. Ray?
A. Mostly from Mr. Ray direct.
Q. What was the purpose of making the gagings there?
A. The purpose was to have a third measurement of the river which was entirely independent of the previous measurements, to see what the agreement would be.
Q. Did Mr. Ray tell you that was the purpose?
A. I believe he told me that.
Q. When was it first determined to make observations there at that point by the Lake Survey?
A. It was talked about in the spring; was finally decided upon in June I believe.

Q. What time in the spring if you remember, was the first talk? That was the spring of last year?

A. I should say March or April.

Q. Did you have any talk with anyone who was not an employe of the Lake Survey, about making measurements, connected with the Lake Survey?

A. I don't recall that the matter was talked of outside of the Lake Survey.

Q. That is no one who was not then connected with the Lake Survey?

A. I don't believe I quite get your question.

Q. Did you talk with anyone about making measurements, who was not then connected with the Lake Survey?

A. Not that I remember.

Q. What were your instructions?

A. My first instructions were to make a reconnoissance of the upper river with a view to selecting suitable gaging sections, preferably in slow water, and after making such reconnoissance and making recommendations to the office, I was instructed to proceed with the measurements of the adopted section.

Q. Who was in the party that made the measurements?

A. My ranking assistant was Mr. Jones. The other technical assistant was a Surveyman appointed for the summer temporarily.

Q. Who was that?

A. A Surveyman. The other members of the party were the ship's crew, and deckhands attached to the party.

Q. How many altogether?

A. At that time I believe the entire party was ten men including myself.

Q. Which section did you measure first?

A. They were measured as nearly simultaneously as possible.

Q. Was the party divided for that purpose?

A. No.

Q. When you say as near simultaneously as possible, just what do you mean? Do you mean that the meters were run at the same time on each section?

A. Oh, no. No, one section was laid out and prepared for measurement and then the other one. When it came to velocity observations, they were taken first on one section and then on the other, usually not observing more than two days on one before going to the other section.

Q. Two what?

A. Two days before going to the other section.

Q. How many observations would you make a day on each section, velocity observations?

A. For discharge measurement do you mean?

Q. Yes?

A. The greatest number of discharges measured in one day was three.

Q. Did you make observations during July and August, each day?

A. Oh, no.

Q. How many did you make altogether?

A. Altogether ten complete discharge measurements were made on each section.

Q. The same number on each section. Covering what period of time?

A. July 30 to August 12 inclusive.

Q. How wide was the Section Wickwire; how wide was the river at that point?

A. About 1950 feet.

Q. How many panels were there?

A. There were ten panels, in addition to what we call the two end areas.

Q. You made soundings, did you, at that point?

A. Yes.

Q. What area did you sound?

A. The entire area.

Q. How far up the river and how far down the river?

A. For this work the soundings were exactly in the plane of the Section.

Q. That is on a line?

A. On a line across the river.

Q. You did not sound above or below that line?

A. Not at that time.

Q. Well, did you do it before?

A. I sounded the entire upper river within the last two years.

Q. How frequently were the soundings made?

A. I believe as close as 75 feet apart.

Q. Is that an average?

A. On the average.

Q. You mean that some of them were closer than that, closer than 75 feet?

A. Some were undoubtedly closer.

Q. How much?

A. I could not say now exactly.

Q. Well, was it close to 50 feet?

A. In shallow water soundings from a row boat or small launch, we frequently went at a very slow speed and soundings were taken about as often as they could be recorded.

Q. And where the water was swift, it was not sounded so frequently?

A. It was not as frequent as that.

Q. What was the greatest distance between soundings?

A. I do not think there was ever 400 feet between soundings.

Q. Now in making your soundings here, in connection with the work that you did on the Wickwire Section, how frequently did you make your soundings?

A. Soundings on Section Wickwire averaged 7.6 feet apart.

Q. What kind of an apparatus did you use to make soundings?

A. The standard sounding weight was a 140 pound fish shaped weight suspended by a plough steel piano wire, about .1 of an inch in diameter. That was wound on the drum of a reel, which was supported on a steel catamaran.

Q. What was the diameter of the drum?

A. The diameter was such that the circumference was about five feet.

Q. When the weight struck the bottom in the course of these soundings, could you see it?

A. You could not see the weight, no.

Q. Did you know where it was with reference to the line of the section?

A. Very nearly.

Q. How did you determine that?

A. Because the wire never deflected from the vertical more than three degrees, above water.

Q. How did you measure that?

A. That was measured on a deflection scale which was fastened under the sheave over which the wire passed.

Q. Well now, maybe the court would not just understand just how that was done. I wonder if you could tell us in the language of the layman about that?

A. The wire in passing from the drum of the reel went over an iron pulley, and descended down into the water from the pulley.

Q. The pulley was on the line of this section was it?

A. The pulley was on the section.

Q. How was that determined; how did you determine whether it was on the line?

A. By standing by the pulley and looking at the side ranges, on one bank or the other.

Q. Go ahead and describe how you measured the inclination?

A. Below the pulley, a board was fastened horizontally and on this board were marks so arranged that as the wire hung vertically the mark denoting zero was right by the wire, and if the wire deflected down stream three degrees, the line marked three would be almost against the wire.

Q. What was the diameter of this weight on the bottom?

A. About eight and a half inches.

Q. How closely was the inclination of the wire read?

A. To the nearest degree.

Q. Where was the maximum inclination of the wire, what point in your soundings on that section?

A. In degrees?

Q. No, where on the section?

A. The deepest part.

Q. How deep was that?

A. The deepest sounding on Section Wickwire was 29 feet.

Q. What was the inclination of the wire at that point?

A. As I recall, it was 3 degrees from the vertical.

Q. Where was the minimum inclination of the wire observed on that section?

A. Near the shore.

Q. What was that?

A. Zero.

Q. You kept a record, did you, of the inclination of the wire at the different sounding points?

A. It was observed on every sounding, I believe.

Q. Did you keep a record of it?

A. It was recorded.

Q. Who read the deflection?

A. I believe I read the deflection myself.

Q. Were there any other deflections observed than the ones that you have mentioned?

A. Not in connection with the soundings.

Q. I suppose it was some place between zero and three degrees, at the different points?

A. Oh, well I stated that the deflection was read on practically every sounding.

Q. What was the depth of the sounding, and what was the

corrected depth in each case, and where were they located? Have you the data here so that you can answer that question?

A. I don't know as I understand your question. We made 218 soundings on Section Wickwire. Every sounding was corrected.

Q. Every one of them?

A. Every one.

Q. You would not correct the zero, would you?

A. There were other corrections.

Q. What corrections would you make?

A. The soundings were all reduced to a common stage. They were all corrected for error in the reel. I do not recall that any other corrections were necessary.

Q. You then say that the corrections which you have mentioned are in your opinion the only ones that were necessary. Is that correct?

A. That is all I can think of now.

Q. What corrections would you make for error in the reel? What do you mean by that?

A. The scale on the reel indicated that five feet of wire had been paid out for each revolution. As a matter of fact, a little less wire was paid out. The correction was determined by measuring 50 and 100 foot lengths of wire on shore, winding them on the reel, and noting the distances by which the beads failed to meet at 10 and 20 revolutions of the drum.

Q. What was a constant correction that you would make in each case?

A. That gave a constant percentage correction.

Q. And with reference to this deflection, you would make correction for that, would you?

A. We would if they had been necessary. The greatest computed correction was .01 of a foot and was accordingly neglected.

Q. You mean by that that when this weight struck the bottom it was only .01 of a foot out of line?

A. I do not. I mean that the length of wire submerged was only .01 of a foot greater than the straight distance from the water surface to the bottom.

Q. How much would the weight be off of the line, off the section line?

A. I could not say exactly.

Q. You never made any calculations?

A. I never calculated. We could give limits beyond which it could not have deflected.

Q. What would be the maximum limit, in your opinion?

A. I make it 1.5 feet.

Q. That is at the deepest point, at 29 feet there that you were speaking about?

A. In that depth, the weight could not have been as much as 1½ feet down stream from the section.

Q. While you were making these soundings, I presume you were on some kind of a boat, were you not?

A. Working from the Lake Survey Catamaran.

Q. Can you describe that catamaran of the Lake Survey?

A. The catamaran is composed of two airtight pontoons of steel, each one about 28 feet long and of 5 foot beam. These are fastened together, or rather held apart by steel trusses, so that the two pontoons are abreast and sixteen feet apart, center to center.

On top of the trusses there is a deck of wood. The catamaran when loaded for work draws about 1½ feet.

Q. How was this catamaran held in place while you were making the soundings?

A. It is moored by a galvanized wire from a float about a half a mile upstream; the float in turn being anchored to the bottom of the river.

Q. Was there any movement of the catamaran at the time you were making these soundings?

A. The catamaran was steadied while making each sounding; then moved—

Q. How?

A. By movements of the steering wheel.

Q. How was this board that you speak of kept in a horizontal position?

A. It was fastened firmly in the horizontal position.

Q. At the time you read the deflection, how did you know that it was in a horizontal position?

A. Because the catamaran is so steady that the tilting would not amount to anything appreciable in reading single degrees.

Adjourned to Wednesday February 18, 1914, 9:30 A. M.

Depositions in the above entitled cause taken before the Commissioner on the 8th day of April, 1914, at 10:30 A. M. at Room 606 Federal Building, Chicago.

Present:

Mr. Albert L. Hopkins,
On behalf of the Government.
Mr. Edmund D. Adcock, and
Mr. Alfred S. Austrian,
On behalf of the Sanitary District.

SVEND K. EMERSEN, a witness called in rebuttal on behalf of the Government, was first duly sworn and testified as follows:

Direct Examination by Mr. Hopkins.

Q. State your full name?
A. Svend K. Emersen.
Q. Where do you live?
A. 3727 Lyndale Street.
Q. What city?
A. City of Chicago.
Q. What is your business?
A. Lake Captain.
Q. By whom employed?
A. Pickand, Mather & Company.
Q. How long have you been a captain on the lakes?
A. The season of 1913, full season; and off and on, taking somebody's place you know, but one full season you might say.
Q. How long have you been navigating the Chicago River?
A. Well last summer practically off and on, and then years before that when I was sailing lumber schooners and barges out of Chicago.
Q. About how many years altogether have you been navigating the river in lumber schooners or otherwise?
A. About three years in lumber schooners and last season in the big fellow.
Q. Last season what size boat did you have?
A. What do you mean, the size boat?
Q. The length?

A. 348 foot length and 48 foot beam.

Q. What draft?

A. All we can get in the Chicago River. We load down to 20 feet, if we can get the water.

Q. What can you draw in the Chicago River?

A. 18 foot 6 is recommended at the present time.

Q. What is the effect of the current in the Chicago River on the navigation, from your experience?

A. That all depends on where you are.

Q. Go ahead, tell us where it does affect navigation?

A. All through the bridges, down in town, down through town; all the way up there, I should judge the current is 2½ to 3 miles an hour. Of course out to the pier you won't get so much current as you do down through the narrow places.

Q. What is the width of the river along about between Madison Street and 12th Street?

A. Oh, all the way from 80 feet and up. I got stuck there last summer; met a boat down here at one of the bridges. We were 48 feet beam and he was 42. One had to get out of the way for the other to get through the bridge.

Q. What place in the river is the current greatest?

A. Well, what you call here around Jackson Street Bridge and all the way up into them narrow places there.

Q. What are the conditions down about 12th Street?

A. Well, there is another hard place.

Q. How many tugs do you use in coming into the river, how many did you use with your boat you had last summer?

A. Two tugs.

Q. Could you come in without tugs?

A. No, they will not let us go up with one tug. You could not handle her with one tug.

Q. Suppose the current in the river were greater, in your opinion what effect would it have on navigation in the river?

A. Close up the Chicago River and make a boulevard out of it. Of course if you are going to have more current there, navigation would be impossible.

Q. What is the name of your boat?

A. Venus.

Q. Where does that boat hail from?

A. Fairport, Ohio.

HERMAN JAENKE, a witness called on behalf of the Government in rebuttal, being first duly sworn, testified as follows:

Direct Examination by Mr. Hopkins.

Q. What is your full name?
A. Herman Jaenke.
Q. You live in Chicago?
A. Yes, sir.
Q. What is your business?
A. Lake Captain.
Q. How long have you been a lake captain?
A. I have been sailing for 12 years steady; last 12 years, captain.
Q. What is your boat?
A. The George N. Orr.
Q. Who owns that boat?
A. The Canada Atlantic Transit Company.
Q. What has been your experience in the navigation of the Chicago River? How long have you been navigating the Chicago River?
A. On and off for the last 30 years; last 16 years steady.
Q. What has been your experience as to the effect of the current in the Chicago River on navigation?
A. Well I should judge the current in the river is about from 2 to 3 miles and we have very much difficulty in going with the current, principally.
Q. What is the difficulty?
A. Well, it interferes with the navigation. For instance, I say, going with the current if they don't give you the bridge, all we can do is reverse our engines and we lose control of the boat entirely.
Q. How about the docks?
A. Well, striking the dock or anything. We have to strike something.
Q. Can you stop without striking the docks?
A. Can't do it. You lose control of the boats, when the current gets—
Q. How many tugs do you use?
A. One, one tug.
Q. What is the size of your boat?
A. We are 326 foot keel.
Q. What is the beam?

A. Beam 42 feet.

Q. How about coming down the river when you meet another boat?

A. Well, for instance between Adams and Van Buren, if you meet a good size boat, we can't pass. There is only one place we can pass and that is right at the elevator, they call it the Manhattan.

Q. Why not?

A. The river ain't big enough; won't let us go by. You cannot go through Adams, Jackson Boulevard, Van Buren.

Q. When you have two boats in the river along there, what effect does that have on the current?

A. Well, you get a whirlpool out of it; about 8 or 10 miles. I had an experience coming in last year. I got stuck in Madison Street, drawing about 17 foot 6; and another steamer tried to pass by in the other draw, in the west draw, and it was impossible for them to get through.

Q. How about damage to the boats, to the docks?

A. Our boats are dented; the bows are all dented in; every one of the package freighters. They are steel. They are all dented in through the momentum. If you are loaded and the current gets hold of you you can't stop; there is no tug can stop you. You are bound to swing into the abutment.

Q. What is the name of the boat you got stuck in the draw with?

A. One of the Lehigh boats; she was the Tuscarora.

Mr. Hopkins: That is all.

No cross-examination.

J. P. MINSKEY, a witness called in rebuttal on behalf of the Government, was first duly sworn and testified as follows:

Direct Examination by Mr. Hopkins.

Q. Will you state your full name?

A. J. P. Minskey.

Q. Where do you live?

A. I live on Orchard Street, 2464.

Q. What is your business?

A. I am a sailor man; been Master Mariner for a good many years, if that is what you call it.

Q. What has been your experience in navigation?

A. Well, my experience in navigating in the Chicago River is confined to two years ago this winter. I have been in a

company that all their business has been from Lake Erie to Lake Superior for 25 years, all only a year ago last winter.

Q. What other work have you done?

A. That was the Gilchrist Transportation Company.

Q. What work did you do for the Gilchrist Transportation Company?

A. I had charge of the steamers we had here that were loading storage grain from the 1st of August up until the following spring. We had 15 ships. They were in Chicago, and they ranged in size from 5,000 tons to 10,000 gross tons.

Q. Are you familiar with the conditions in the Chicago River as to current?

A. Yes, sir.

Q. And its effect on navigation?

A. Through that winter I got very familiar with it, because I had a lot to do with it, every day moving boats. We had a good many boats laying along the South Branch, and in fact both branches of the river; but we did not have a ship lying to the dock in the South Branch that we did not have from 1 to a half dozen bills of damage against them. That is every boat that would go by would damage us, mostly.

Q. What caused that?

A. That was caused from the current in the river; the boats being large and heavy, every boat that would go along by, they would hit them, rub them and the current would catch them on the bow and shove them right head first down into us.

Q. What were the names of those boats that you had charge of?

A. There was the steamer Gilchrist, I think I had six damage bills on her. The steamer Lake Shore, I had several damage bills on; the steamer Neptune, several damage bills. I could not say how many on each one without I had a book and looked it up; but the Mars, the Saunders, and the Oglesby.

Q. What were some of the other boats in that 15 you had charge of? Do you remember the names of the other boats?

A. Oh, I could not call them all right offhand.

Q. Where were these boats lying?

A. These boats that I speak of were lying in the South Branch.

Q. Where?

A. Well one was lying just above Taylor Street, between Taylor Street and the Little Railroad Bridge. There was another lying just below 18th Street.

Q. Which one lay at Taylor Street, just above Taylor Street?

A. The Neptune.

Q. Go ahead.

A. The Gilchrist laid at 18th Street, and the Saunders laid just below 18th Street. Well now, there is this about that: We were moving them. There was not one of those boats in this time we did not load and unload from 2 to 3 times, 4 times some, and we were moving them.

Q. In a general way we want to know where they were lying when damaged?

A. This Gilchrist laid just above 18th Street Bridge, on the east side of the river. You come down and come through the Pennsylvania Railroad Bridge, you know and we were lying right down on the east side of the river there between the Pennsylvania Railroad bridge and 18th street bridge on the east side of the river above 18th Street, south of 18th Street. I speak of this above and below as I used to know it 25 years ago. They have got the damn current running uphill now and I am liable to call it up when it is down, maybe.

The Mars laid below 18th Street Bridge on the west side of the river awhile. Then she laid up the river awhile, up above 22nd Street.

Q. Any damage to it?

A. She got damaged up there, yes, sir. She got damaged so that the plate that comes up to the angle iron that forms part of the deck, the deck comes on, turned the whole thing over, stanchions and timberheads, and a lot of stuff, turned them over there for, oh 50 feet. There was a lot of damage; cost us a lot to get that fixed up.

Q. Would you consider it dangerous now to navigate the Chicago River?

A. It surely is. You can't go up and down this river. Now I did not move a boat, not one of those that winter, without having more or less damage on them; when in the South Branch; the North Branch not so bad.

Q. How many tugs did you use?

A. We used from two to six on a boat.

Q. Did you ever get stuck in the river?

A. Yes, sir, I was stuck with the Steamer Lake Shore in the Pennsylvania Railroad Bridge. We came down, we laid at one of the elevators, the Santa Fe I think, but we came down there and stuck. We had two tugs, one tug ahead and one tug astern. We went into the draw of the bridge and I

was stopped, and bye and bye you could see the water rise up ahead of her, where she blocked it up. And bye and bye she backs, went and backed right up, the river—

Q. Just when was that?

A. I should say it was in March.

Q. Of what year?

A. 1912, two years ago this winter.

Q. What draft did you have?

A. We tried it twice and could not get through. We laid her to the dock and waited a day. I notified our agent here, Mr. Sullivan, and we waited a day and we thought we had a fine time, the water was high. He thought maybe we were on the bottom, but I told him we could not—that could not be because we only were about two thirds loaded. We tried it again, and this time we had two tugs ahead,—the second day, I think we waited two days and the second day we had two tugs ahead and a tug on each quarter, and she did the same thing with us. That time, we only tried it once. I said that was expense enough, we would back out. The second day following, they shut down the Drainage Canal or checked the water so that one tug took us over and brought us down.

Q. One tug?

A. Yes.

Q. What was she drawing at that time?

A. She was drawing about 16 feet.

Q. Can you draw 20 feet in the Chicago River?

A. No, sir; at least they said it was not safe to load over 18½ feet and I did not load any of the boats over 18½ feet. We had one of them through mistake, that loaded at the Santa Fe, the Saunders, I left a ship keeper and the man in the elevator to load her and they got her down to 20 feet. She got on the bottom up in the end of the slip when she was drawing 20 feet. When we got out and had steam on again we went down again and they lightered it for us without charging any extra, because the elevator man said it was his fault. We lightered her to 18½ feet, and we came down with it in the end.

Q. Is the river at least 200 feet wide?

A. I never measured the river. It would be only a pure guess, or guess work on my part, to say how wide it was. I know our big boats that are 54 or 55 or 56 feet seem to fill it up pretty well.

A little later in the season, I took the Steamer Neptune from Taylor Street to take her up to the North Branch to

unload her; and we were all day at Washington Street, while they were building that new bridge. The cofferdam, a little of the river got shut off on the other side, filled in some dirt along on the cofferdam, and she was only loaded with oats, light draft, probably less than 16 feet. But we were all day there trying to get her across the pinch in the river where it had been narrowed up. The current was so strong, and we had at one time, on this day that we worked there, we had four tugs on her, a tug on each quarter and two tugs ahead. The tug ahead was the Towing Company's tug, and they got another Towing Company to help them. The tug after, it was steering us, it was a Towing Company tug; and a Dredging Company's big tug dropped along on one quarter, and he said he could push us over alone. But we didn't get over. And I took a brand new cable, and then Captain Bob Young, he was up there bossing his tug and I was bossing the job and Mr. Sullivan's man from his office was down there to help us out. And we did not get over. I had a brand new cable that I had borrowed from one of our bigger ships, 10,000 ton boat, one inch and an eighth cable, a new one. I took a bight of that and put it over a clump of spiles they had to protect this cofferdam. I was going to keep her there and block the river all night; but she pulled the clump of spiles down and I thought it was not safe to stay, so we had to back up the river a half mile to get a place to stay over night. The next day they shut down the Canal again and we got over the next day.

Q. When was that?

A. This was the same winter, I think in March, later in March.

Q. 1912?

A. When we got over, we got over so fast that we took a sheer and went into the West Approach to Lake Street Bridge, and they have no spiling around it at all and we took the wheel strakes off of her. They sheared one of the angle irons off of the stone work and put a big dent in the bow you could walk into, on the stonework of the West Approach. The boys thought she was not going very fast and she cuts the protection on the bridge.

Q. Would there be any difficulty in navigating the river if the current was a mile and a quarter an hour?

A. Why I would not think so. I would not think it, a mile and a quarter. That is all guess work on my part, for I am not an expert on this current business. But I should think

we ought to navigate it without much trouble, if it were not higher than that.

Q. Do you navigate the river in Cleveland?

A. Yes, sir, I have been up the Cuyahoga River a great many times. We go up there sometimes without a tug. I have been up there a good many times without a tug. It is a good deal narrower than our river here, a good deal crookeder, a good deal crookeder, and a good deal narrower. There was one place where it ain't more than a length of a ship, from here (indicating) right across to two parts of the bridge, a regular oxbow, right around. We would navigate it and go up and go to the furnace without damage, because there is no current. We can stop the boat. We can go slow; if we can't steer her, we would heave out a cable on one side and a cable on the other and pull her up to that part or pull her back. And we would usually have a tug ahead, but in case where we have had tug strikes we have been up there without a tug. I have been up there twice without a tug and come down again. That would be as far as it would be from the forks of our river up—well, as far as the river goes, the Santa Fe Elevator. And we have no trouble to navigate it and do it without damage. And lots of the places there is not room for three boats abreast, that is for the boat on each side; you can't get your boat through between, lots of places in it.

Q. In your opinion, what is the current in the Chicago River?

A. Well, I have seen it over ten miles when we have been trying to get through these bridges; as I tell you, going alongside of you like a mill tail, when a man could not run and keep up with it.

Q. You have it partly dammed up?

A. You have it partly dammed up. But I should think in the least calculation it is five miles in those bridges all the time, in those close places. While they have been building that Pennsylvania Railroad, I would say it averaged five miles an hour in the draw of that bridge.

Q. Did you ever test it by dropping things in and trying to walk with it?

A. Yes, sir, I had a man undertake to walk up a ladder with a box of provisions, and the ladder broke and he went into it and we came darn near losing him by sucking down under the boat, we just fished him out and that is all we did do.

Cross-examination reserved.

ARNOLD GREEN, a witness called in rebuttal on behalf of the Government, was first duly sworn and testified as follows:

Direct Examination by Mr. Hopkins.

Q. State your full name please?
A. Arnold Green.
Q. What is your business?
A. Lake Captain.
Q. How long have you been a Lake Captain?
A. Since 1887.
Q. What company are you connected with?
A. Have been with the Chicago Steamship Company up to last fall.
Q. What boat did you navigate?
A. City of London.
Q. What is the size of the boat?
A. 297 feet keel and 41 feet beam.
Q. How much experience have you had in navigating the Chicago River?
A. Well, for 34 years I have been on this river.
Q. What is your opinion as to the effect of the present current in the river upon navigation?
A. Well, it is dangerous to navigate the river; has been since the current came here.
Q. What is your opinion as to what the current is?
A. Well, that varies; depends upon where you take it.
Q. Take the narrow places?
A. At Halsted Street and Pittsburg Ft. Wayne Bridge and 12th Street, and this place down here between Van Buren and Jackson, that is the most difficult places.
Q. What do you think the current is at those places?
A. Oh, they go three or four miles an hour any time, I should judge, the way it looks to us.
Q. What would be the effect if you had any greater current in the river?
A. Could not navigate at all as far as I could see.
Q. Have you ever had any trouble?
A. O, lots of it.
Q. Have you ever been stuck?
A. No, I never was stuck.

Q. What kind of a boat do you have, as far as power is concerned?

A. It is a powerful boat.

Q. What speed can you make?

A. Oh, about 11 miles an hour loaded.

Mr. Austrian: Q. What tonnage?

A. 2,000 tons gross tonnage; carry three thousand tons of freight.

Mr. Adcock: Q. What is your draft?

A. 18 feet.

Mr. Hopkins: Q. What do you consider the worst place in the river?

A. Oh, for handling a boat 12th Street is a bad place, on account of the cross current there.

Q. Just how does that operate on a boat?

A. It will catch one end of the boat and swing it around you know, long boats.

Q. There is a turn there, is there?

A. Yes, there is a turn there; coming down the river it will catch your stern and you will swing into the bridge, and going up it will swing the bow the other way and swing the stern into the bridge.

Q. Do you use a tug?

A. Yes, use a tug always going up the river with the current, have to.

Mr. Adcock: Q. With the current?

A. Yes.

Mr. Austrian: Do you use it coming down?

A. Once in a while if I am drawing 18 feet or more.

Q. If you are drawing what?

A. If I am drawing 18 feet of water, I usually take a tug.

Cross-examination reserved.

W. D. HAMILTON, a witness called in rebuttal on behalf of the Government was first duly sworn and testified as follows:

Direct Examination by Mr. Hopkins.

Q. State your full name?
A. W. D. Hamilton.
Q. Where do you live?
A. 2431 South Lincoln Street, Chicago, Illinois.
Q. What is your business?
A. Ship Master and Marine Superintendent.
Q. Are you familiar with conditions in the Chicago River?
A. I am.
Q. Who are you working for?
A. Edward Hines Lumber Company.
Q. What is your experience with the Chicago River, how long, and what have you done?
A. I have been sailing in here for about 34 years, since 1879.
Q. What is the width of the river?
A. The width of the river will vary from—in my estimation from 80 feet to about 240 in the narrowest place.
Q. What was the narrowest place?
A. 80 feet, in that neighborhood. I might be a few feet out of the way there, not much.
Q. At Jackson Street there is a draw, isn't there?
A. Yes.
Mr. Adcock: Q. Where is that narrow place?
A. The narrow places would be at Jackson, Adams and Van Buren Street and the Metropolitan Railroad Bridge, the narrowest part of the river.
Mr. Hopkins: Just what effect does that draw at Jackson Street have?
A. Well, it is a very narrow place. I do not consider it the worst place in the river.
Q. How about the by-pass there, there is a by-pass?
A. The by-pass carries but very little water through it. I have visited that proposition several times and looked at it and noticed that the current through the by-pass is very much slower than it is through the main body of the river. In fact very little water moves through the by-pass.
Q. What is the current in the river.

A. I should think it varied from two miles in the widest part of the river to up as high as 3½ to 4 miles in the narrow places.

Q. Where would you say it was 3½?

A. Along—well, take Polk Street Bridge for instance and at 12th Street. Understand I do not mean that this current would be that speed for the full width of the river, but where it strikes these corners and goes around these corners it is much faster and a much more dangerous proposition. It forms a strong cross current and takes absolute control away from the ship entirely.

Q. Is that the part of the current that affects navigation?

A. That is the part of it that affects it the most. The cross currents is the worst thing we have to contend with. If the river was the same width all through, so that we had the same current to contend with at all points, it would not be quite as difficult to navigate as it is now.

Q. What effect does that current have upon navigation?

A. Why it makes a ship practically unmanageable and if she was of any size at all and she didn't have considerable tug service attached to her, she would be unable to do anything. She would go across the river.

Q. The boats you have charge of are usually small boats?

A. Smaller type.

Q. Lumber boats?

A. Lumber boats from 156 feet long to 230 feet long.

Q. What beam?

A. Beam from 28 to 40 feet.

Mr. Adcock: What is the draft?

A. Draft, extreme with us would be about 16.6.

Mr. Hopkins: Q. You do not navigate the North Branch?

A. Yes, sir, we go all over the river; go north to deliver lumber, to any lumber docks in the city; several loads last year to the Hettler Lumber Company.

Q. What do you consider the worst place in the river?

A. 12th Street is a very bad place and Halsted Street is very bad; the current there at 12th Street, a fellow going up the river if he gets—

Q. When you say up the river you mean away from the lake?

A. Going south, when a ship gets clear of the abutment, the current will generally catch the stern and drag it over to the west bank, unless he has got a tug to hold it. And when

he is coming down the river or going north, the same thing applies to the bow. It catches the bow in entering the draw. We invariably go through the east draw; it will catch your star board bow and drag you into the abutment. We had one boat, the smallest boat we got, we had three damage jobs in one season. That was at 12th Street, all on the same spot on that account.

No cross-examination.

JOHN SIMONS, a witness called in rebuttal on behalf of the Government, was first duly sworn and testified as follows:

Direct Examination by Mr. Hopkins.

Q. State your full name?
A. John Simons, 6348 Maryland Avenue, Chicago.
Q. What is your business?
A. Lake Captain.
Q. How long have you been a lake captain?
A. Seven years.
Q. For what company?
A. Canada Atlantic Transit Company.
Q. What is your boat?
A. Arthur Orr.
Q. Sister boat to the George M. Orr.
A. Yes, sir.
Q. How long have you been navigating the Chicago River?
A. 20 years. Well, I have not navigated it that long. I have went up and down it for 20 years.
Q. What is the rate of the current in the Chicago River?
A. Oh, I should say around 2 or 3 miles an hour. Sometimes more. I do not think there is any time it is below that.
Q. What is your opinion as to whether or not it is dangerous to navigate the Chicago River under present current conditions?
A. I think it is dangerous, to avoid damage in navigating it. Anybody navigating the Chicago River, to my estimation, are in danger of damaging their steamboat every time they go up.
Q. What are the chief difficulties and where?
A. Why, the biggest part of the current, or the worst

place, is take it from Jackson or Madison Street to Van Buren, and then take it at 12th Street and then again at 16th Street, the railroad bridge; then again at the Pennsylvania Bridge and also at Halsted Street.

Q. What kind of freight do you carry?

A. Package freight, merchandise, and flour and feed also—

Q. Give us the dimensions of your boat?

A. 334 feet long, that is clear; 40 foot beam.

Q. What draft?

A. Carry about 4500 tons on 18 foot draft.

Q. What draft can you load to?

A. Well, about 18 feet, load of grain.

Q. If you had all the water you wanted, could you load deeper than that?

A. Very little deeper we could load. I could load 19 feet, full load of wheat. That is all.

Cross-examination reserved.

Recess to 3:00 P. M.

After recess, 3:00 P. M.

ARNOLD GREEN, resumed the stand and testified further as follows:

Cross-Examination by Mr. Austrian.

Q. Captain, I understood you to say that you had navigated the waters of the Great Lakes for 34 years?

A. Yes.

Q. You began in 1880?

A. Yes.

Q. Will you indicate please just what part of the Great Lakes you navigated?

A. From Chicago to Buffalo, Duluth, Kingston, Oswego.

Q. Through the Soo Locks?

A. Through the Soo Locks and through the rivers.

Q. And by reason of that occupation for that length of time, you were at that time and continuously since have been very familiar with the waters referred to?

A. Yes.

Q. In 1880 and for some years thereafter, what was the size of the boat or boats which you navigated or took part in navigating?

A. Oh, they were about three or four hundred ton.

Q. Three or four hundred ton?
A. Yes.
Q. When did you undertake to navigate a boat of the size of the one you are now navigating, some 2,000 tons?
A. About 12 years ago.
Q. 12 years?
A. 11 years ago, rather.
Q. What was the size of the boat that you navigated in 1900, and immediately prior to that?
A. Oh, about 400 tons, four or five hundred tons.
Q. What length?
A. Oh, 140 feet.
Q. What draft?
A. About 12 feet.
Q. Did you have occasion to observe the conditions in the Chicago River prior to the opening of the Sanitary District Canal?
A. Yes, sir.
Q. Do you recall at or about what time that was opened?
A. Yes.
Q. When?
A. When the Canal was opened?
Q. Yes?
A. In 1900.
Q. 1900?
A. Yes.
Q. You passed up and down the river and made deliveries of freight and picked up freight during the course of the years immediately preceding that, did you not?
A. Yes.
Q. What was the condition of the Chicago River with reference to its navigability for the years preceding 1900?
A. Oh, it was bad.
Q. It was bad?
A. Yes.
Q. How bad?
A. Well, there was no water in it.
Q. No water in the Chicago River prior to 1900?
A. To speak of. Always had trouble with the water.
Q. Speak a little louder please.
A. Always had trouble with the deep drafted boats.
Q. What were the bridge conditions prior to 1900?
A. Well, they were pretty near all center pier bridges of course.

Q. Hard to navigate by reason of those center pier bridges, wasn't it?

A. Yes.

Q. What was the condition of the river with reference to its depth, what effect did that have upon navigation?

A. Well, you would get aground of course, stuck.

Q. When did you begin to see improvement in the conditions of the Chicago River with reference to its navigability?

A. I can't tell that; it comes so slow.

Q. Approximately when?

A. I could not say that.

Q. Sir?

A. I could not say that; that would come so slow that I could not say what time.

Q. Were they better after 1900 than before?

A. In the line of depth of water, yes it was.

Q. And clearance, in width of the river?

A. Well, I can't say that.

Q. You have seen no widening of the Chicago River?

A. Oh, yes, I have seen that all right enough.

Q. To what extent?

A. Well, it is probably—I don't know how much wider but considerably. It was 50 to 75 feet in some places.

Q. In mostly all of the places where it was theretofore very narrow, the river has been considerably widened since 1900, has it not?

A. Yes.

Q. And have you noticed any improvement in the conditions of the river with reference to its navigability due to the removal of center pier bridges?

A. Yes.

Q. Have you noticed any improvement Mr. Green with reference to the odors, the smells in the river?

A. Yes, sir.

Q. What was the condition in the Chicago River prior to 1900, with reference to its sanitary affect?

A. Bad.

Q. How bad?

A. Well, it was smelling.

Q. How bad was it smelling?

A. Well, that I could not say.

Q. It was enough almost to nauseate you, make you sick, wasn't it?

A. Yes, sometimes.

Q. What has it been since 1900?
A. Pretty good in the south branch.
Q. Also as good as in the lake, isn't it?
A. Yes. Today it is very bad, the river.
Q. With reference to the way it looks or smells or what?
A. Don't smell; it looks bad.
Q. The lake looks bad too, doesn't it?
A. I guess so.
Q. It is roiled up?
A. Yes.
Q. On account of the winds and the storms?
A. Yes, on account of what they dump out there.
Q. What they dump in the lake?
A. Yes.
Q. What are they dumping in the lake?
A. Dump all they dig out of the river, I guess.
Q. They dump into the lake?
A. Yes.

Q. Mr. Green, the United States Government has been dumping into the lake in furthering of its work in excavation and so forth, has it not?

A. Probably is.

Q. Prior to 1900, how frequently were there collisions in the navigation in the South Branch of the Chicago River?

A. I could not say.

Q. You have had a lot of experience there, had a lot of observation?

A. Yes, but I could not say how frequent. There was not as much damage as after the opening of the canal. There was not as much, not as serious.

Q. Were they any?
A. Oh, yes, there were some of course.
Q. Quite frequently?
A. Well, I guess so.
Q. Sir?
A. Probably.

Q. Prior to 1900, the great occasion for collision and so forth, was due to the fact that the river was narrow and ships used to bump into each other in navigating the North Branch?

A. Yes.

Q. Since then the collisions you have heard of and that have been spoken of were collisions that were due to a boat swinging into a pier abutments or bridge abutments?

A. Yes.
Q. Is that right?
A. Yes.
Q. How many times would you say you have passed up and down that river in your steamboat, or in other steamboats on which you were, on an average per year in the last 20 years, Captain Green, 10 or 15 times a year?
A. Yes, at least.
Q. 25 times a year?
A. No, not that many.
Q. 15 or 20 times a year would be a fair average would it?
A. Yes.
Q. How many times have you seen boats stuck in any portion of the river in any of those trips you have made since 1900?
A. That I could not say.
Q. Give us your best judgment?
A. I could not judge of that.
Q. Well, as many as three times?
A. No, more than that.
Q. As many as 13 times?
A. Probably about that.
Q. About 13 times in all your experience. How many collisions would you say you have knowledge of or known about that occurred in the 14 years before the Sanitary District Canal opened?
A. I could not say.
Q. How many vessels did you see stuck in the river prior to that time?
A. I could not say that.
Q. Many?
A. I could not say that.
Q. You don't remember at all?
A. No.
Q. The vessels now are very much larger too than they were then?
A. Yes.
Q. The draft is very much deper?
A. Yes.
Q. The beam is very much wider?
A. Yes.
Q. And the tonnage capacity is very much greater is it not?
A. Yes.

Q. When you first started to navigate in the Chicago River in 1880, there was rarely a boat if any that came into the Chicago River that had as much capacity or was of as great a size as the one you are now operating. That is correct, isn't it?

A. Yes.

Q. And the boats that are navigating in the river now, referring to the freighters, Captain Green, are nearly all as large or larger than the boat you operate?

A. Yes.

Q. You spoke of some bad places in the river. You spoke of Van Buren Street, Jackson Boulevard, Madison Street, 12th Street, Pennsylvania Railroad Bridge at Stewart Avenue and Halsted Street?

A. Yes.

Q. Those are the only bad places you know of, or the worst of the bad places you know of. Is that correct?

A. Yes.

Q. Do you remember operating on the Chicago River in 1892, at the time they had the big storms?

A. Yes.

Q. That is when you got flows towards the lake, the river flowed toward the lake then?

A. Yes.

Q. What was the condition of the river with reference to navigation during those freshets and storms during 1892, in 1892?

A. Well, could not navigate. They stopped, tied up everything.

Q. Navigation stopped for a long period of time, didn't it?

A. For a week or so I guess.

Q. And those storms and freshets were so bad, and such a torrent rushing in the Chicago River that it is a matter of common knowledge that boats were rubbed off by the storms from their moorings at the docks?

A. Yes.

Q. Carried out into the lake and smashed against the bridges and so forth?

A. Something like that.

Q. And all by the flow of current and flow of water in the Chicago River?

A. Yes.

Q. How many like conditions do you remember since that time?

A. Well, that would be pretty near all the time now; water running the other way, that is all the difference.

Q. While the river was flowing into the Lake, how many like conditions were there?

A. What?

Q. How many like conditions do you remember before the water was turned in 1900?

A. How many times before?

Q. Yes, or since?

A. Since. Oh well,—

Q. Before 1900? Many?

A. No, I don't remember any. The way I look at it, it is as bad just now as it was then in them freshets.

Q. I am coming to that. It is even worse now than then?

A. Practically the same.

Q. I am coming to that in just a minute, but I want to know how many of those similar conditions occurred within your recollection before 1900?

A. Before 1900?

Q. Yes?

A. Three I think.

Q. Three. When navigation was completely stopped?

A. Yes.

Q. Captain, how fast would you say that the water was pouring down the Chicago River into the Lake during those freshets and storms that you speak of prior to 1900?

A. Well, four or five miles an hour I should judge.

Q. Will a current of four or five miles an hour in the Chicago River tear a boat away from its moorings and away from the dock where it is tied?

A. It might if it is striking the right way.

Q. I am talking about in the Chicago River where the boats are lined up parallel to the flow of the river, and properly secured, a current of four or five miles an hour—

A. I don't know of any boats that broke adrift, I don't remember that.

Q. You don't?

A. No.

Q. You want us to understand that at the time of the freshets the current in the river towards the lake was only four or five miles an hour?

A. Well, something like that.

Q. Something like that?

A. Yes.

Q. But still boats could not navigate?

A. No, they would not take us down, would not tow or anything.

Q. Would not tow. You could not get down by your own steam pressure?

A. No.

Q. How many times since 1900, have those conditions arisen, where they would not tow you and you could not go by your own steam pressure?

A. You would tow and do the damage—

Q. No, please answer the question: How many times have similar conditions arisen where you would not be towed down the river and you could not get down by your own steam?

A. I don't remember.

Q. You don't remember any, do you?

A. No.

Q. Sir?

A. I don't remember any—yes, I remember once.

Q. Tell us about that?

A. Well, that was in the spring of 1908.

Q. Yes.

A. I done a lot of damage that day so I ought to remember it. That was in the North Branch.

Q. You did a lot of damage that day?

A. Yes.

Q. The current was very strong in 1908?

A. Yes.

Q. Due to the Sanitary District Canal and the opening of the Canal?

A. I don't know, due to the cloud burst I understand. I was not around when it happened, and came in during the night. There was no current in the river, in the main branch, but there was a big current in the North Branch.

Q. You never found any current in the North Branch due to the Sanitary Canal?

A. Not to affect navigation.

Q. Not to affect navigation at all?

A. Except at that time.

Q. You heard after you got out it was due to a cloud burst?

A. Yes, to a cloud burst.

Q. You don't want to charge that against the opening of the Canal do you, the cloud burst?

A. No.

Q. What?

A. No.

Q. Now Captain, I believe you testified on your direct examination in reply to the question put to you by the learned counsel on the other side that the current in the Chicago River since the opening of the canal was in the open places from 1½ to 2 miles. Is that correct?

A. I think I said 3 miles, in some narrow place.

Q. I am talking of the open places?

A. Open places?

Q. 1½ to 2 miles in your judgment. Is that correct?

A. Yes. I think I said 3 miles in narrow places.

Q. I am talking about the open places?

A. Open places, that may be.

Q. How much will you say now the current was or is in the open places?

A. Well, it is hard to say that. It is difference in the current. I know it has been running 3 miles an hour sometimes in the open places.

Q. As much as 3 miles an hour?

A. Yes, sir.

Q. At other times less than that?

A. Yes.

Q. At other times I am talking about, not at other places?

A. Yes.

Q. How much less than that at other times?

A. 1 or 2 miles.

Q. Other times less than a mile?

A. Yes, I seen it dead.

Q. What was the most you ever heard of its running in the open places?

A. Oh, I never measured it so I could not say.

Q. You never measured it when you concluded it was running 3 miles an hour?

A. I kind of guessed that.

Q. I want you to guess the same way at the other time, give us the same sort of a guess?

A. How fast it had been going?

Q. Yes?

A. Well not over five miles.

Q. You heard some witnesses testify here it was going as much as 10 or 12 miles an hour, didn't you?

A. I guess I did, yes.

Q. Did you ever see it run as much as 10 or 12 miles an hour anywhere?

A. No, I could not say that.

Q. Ever see it run as much as 8 miles an hour anywhere?

A. No, I could not say that either.

Q. Did you ever see it run as much as five miles an hour in your opinion, anywhere?

A. Yes.

Q. Where?

A. Well, in the narrow places.

Q. Tell us where?

A. Well, that would be Halsted Street and them bridges we name.

Q. The places I named, the bridges?

A. Halsted Street, Pennsylvania Bridge.

Q. Have you seen any widening in your observations of those narrow places?

A. No, you can't widen them.

Q. Can't widen them on account of the bridges?

A. Yes.

Q. What width are those places you indicate as narrow places immediately North and South of the bridges?

A. They are regular width of the river.

Q. Regular width of the river. What is the regular width of the river?

A. I don't know, something 150 to 200 feet.

Q. Do you know any place where it is less than 200 feet since the Sanitary Canal has been opened, except just at the bridge abutments?

A. 200 feet?

Q. Yes?

A. I don't know how wide it is at the Pennsylvania Railroad Bridge. It is not very wide there, West of it.

Q. I don't mean the bridge. I mean immediately North or South of the bridge.

A. West of it there. I don't think it is over 150 feet.

Q. The bridges, places other than at the bridges, the river is at a uniform width practically isn't it? The South Branch I am talking about?

A. No, not all over. There is places where it is narrower.

Q. Substantially all it is one width?

A. Yes, there is places where it is narrower.

Q. But substantially, the great length of the south branch of the river, it is substantially 200 feet or over is it not?

A. It may be.

Q. And the narrow places you speak of are the sections we will refer to as the Bridge Sections of the river, where the bridges are placed?

A. Yes.

Q. That is by reason of the fact that the abutments are there, you haven't got quite as wide a stand to navigate the river. Is that correct?

A. Yes.

Q. Prior to the Sanitary District making these improvements, you had a number of tunnels under the river too, didn't you?

A. Yes.

Q. Where you could only draw something like 15 or 16 feet of water?

A. 16, I guess.

Q. And those have been removed?

A. Yes.

Q. And prior to the Sanitary District making these improvements, the river at many places was not over 16 or 17 feet deep at that time?

A. That is all.

Q. Since then the river has been widened and deepened to an extent of 26 feet, hasn't it?

A. No.

Q. No?

A. 18½ or 19 feet.

Q. Where is it only 18½ feet?

A. Well, where we get—there might be some deep holes some places, but there isn't that much water.

Q. There isn't that much water. You can't point out any place where the navigable part of the river is not 26 feet deep can you?

A. No, I cannot.

Q. Have you ever gone aground anywhere?

A. Yes.

Q. Tell us where?

A. I have been aground in the North Branch many places.

Q. I am talking about the South Branch?

A. Well, that Pennsylvania Bridge, several times.

Q. That is at the bridge?

A. Through the bridge.

Q. Of course you know you can't deepen that river there without loosening the abutments of the bridge until they remove the bridge, you know that, don't you?

A. Yes, I guess so.

Q. And they are removing the bridge, aren't they?

A. Probably are; maybe that will be a long time.

Q. What other place or spot have you found the water shallower than 26 feet?

A. At the Rock Island Elevators, there is no water at all sometimes.

Q. You mean next the dock?

A. Well, quite a distance out, south of 12th Street there.

Q. South of 12th Street?

A. Yes.

Q. Don't you know that there is no place in the navigable part of the river less than 30 feet deep, and prior to the opening of the Sanitary District Canal there was no place that was deeper than 16 feet?

A. No, that is not so.

Q. That is not so?

A. I have been aground in the forks a couple of times.

Q. We will get to the forks after while. We are only at the spoons.

A. Right next to the bridge.

Q. We will get to the forks in a little while. Mr. Green, is the water as deep now at the Rock Island Elevator as it was in 1911?

A. I don't know.

Q. You don't know?

A. I know that bridge, once in a while of course we can get that.

Q. I am not talking about the exceptions. I am asking you whether as a general proposition is the water as deep at the Rock Island elevator now as it was in 1911?

A. I don't know.

Q. I will ask you whether or not immediately opposite the Rock Island elevator, the depth of the water was not 27.2 feet in the middle of the stream, or approximately the middle of the stream, immediately opposite the south part of the elevator; 26.4 feet immediately opposite the middle part of the elevator and 29.9 and 27.4 feet immediately opposite the North end of the Rock Island elevator. Can you answer that question?

A. No.

Q. You don't know?

A. I don't know.

Q. Now you spoke about Van Buren Street being a bad spot and that you had been stuck at Van Buren Street. Is that right?

A. No, I was not stuck, but I needed all the power I could get through there.

Q. You neded all the power you had to get through?

A. Yes.

Q. Prior to the opening of the Sanitary District Canal in 1900, what depth of water was there at Van Buren Street?
A. 16 feet I suppose.
Q. How much is there now?
A. I don't know. It is more than 18 feet anyway.
Q. It is more than 18?
A. Yes.
Q. If I should tell you it was 26 feet, would you think that my statement was incorrect?
A. Yes, I would think it might be a deep hole there, but it would not be for any distance.
Q. Not for navigation purposes?
A. I mean not for any great distance. It might be a hole, of course.
Q. There would not be much sense in digging a hole to improve navigation?
A. No, but those holes were probably formed by the current.
Q. If I said to you Mr. Green that the depth through the draw at Van Buren Street at its shallowest spot is 20 feet and at its deepest spot is 24.1 feet, would you say in your opinion my statement was incorrect?
A. Oh, that may be so.
Q. And that at the 200 foot point immediately south of the bridge, the depth at no point is less than 22.7 feet, would you say that statement was incorrect?
A. No, I could not say one thing or another.
Q. And immediately north of the bridge at no point was it less than 24.9 in the navigable part, would you say that statement was incorrect?
A. I don't believe that.
Q. You don't?
A. No.
Q. Have you ever had occasion to think, since the opening of the canal, it was less than that?
A. Well, I have been rubbing on the bottom there. It may be now.
Q. Since the Van Buren Street tunnel was out?
A. I believe so.
Q. When was the Van Buren Street tunnel removed?
A. I don't remember now.
Q. You don't remember?
A. It is not very long ago.
Q. I beg your pardon?

A. It is not very long ago but I don't remember what year it was.

Q. You haven't any recollection of having rubbed the bottom since then at Van Buren Street?

A. How long ago is it now since it was?

Q. Mr. Wisner says he thinks it was 1910 or 1911.

A. Maybe not since then.

Q. Now Mr. Green, if the bridge span at Van Buren Street is enlarged, it being now only 94 foot opening, would that in your opinion greatly improve the opportunity of good navigation at that spot?

A. How much do you say, how much difference?

Q. If the 94 foot opening was enlarged say to 180 feet?

A. Sure, alter conditions altogether.

Q. Alter conditions altogether? And the open span at Jackson Boulevard, the place you say was dangerous to navigation is only 92 feet?

A. Yes.

Q. That is about your understanding of it?

A. Yes.

Q. If that span is enlarged to make it between 160 and 170, would that remove 1 of the dangers you have referred to?

A. Yes.

Q. And the Metropolitan Bridge the same way?

A. Yes.

Q. You know the Government has condemned the Metropolitan Bridge, and that is in the process of being removed?

A. Yes, kind of slow in moving it.

Q. And the city bridge at Jackson Boulevard is in the process of being removed?

A. Yes, I seen something of that.

Q. Those improvements will greatly improve the navigability of the Chicago River?

A. Oh yes, sure.

Q. And if the—

A. The building south of Van Buren Street, what are you going to do with that?

Q. The building south of Van Buren Street? And that in the improvement that is now under way will be removed also and the river widened?

A. That is a dangerous place.

Q. You mean the Loop power house building?

A. I guess that is a power house.

Q. You know that already steps have been taken to condemn that property and enlarge the river at that point?

A. Yes.

Q. You know Captain, do you not that the river has been widened each side of the Union Loop Power House? You have seen that, haven't you?

A. Yes, I seen that; yes, south and north.

Q. South and north of it, to 200 feet?

A. Yes.

Q. That has all been done since the opening of the canal?

A. Yes. I just was wondering why that building was there. Everybody asked me that question.

Q. At the Madison Street Bridge, you say that was another dangerous point?

A. There is one.

Q. A 60 foot opening on the west side and a 55 foot opening on the east side?

A. Yes.

Q. You know that is a center pier bridge, you remember that?

A. How much water is in that draw, may I ask?

Q. Yes, 21 foot.

A. Yes.

Q. How much do you think is in that draw?

A. I didn't think it was over 18; may be now.

Q. You go through with a 18½ foot load?

A. We go through; that is all too.

Q. We will come to that in just a minute.

A. Make no headway.

Q. If I told you that in the middle of the stream between the west abutment and the center pier the depth runs from 24 to 26 to 20 feet, and the east side from 28 to 26 to 18 immediately next to the dock line, would you say that I was misstating the fact, or don't you know about it?

A. In the Madison Street?

Q. Yes?

A. The east draw?

Q. 28.6 and 26.6 in the navigable part of the river.

A. Now?

Q. In 1911, 14th day of December 1911, and immediately next to the dock line 18.1 feet, would you say that was not correct?

A. I don't think so, I don't think so.

Q. How much less would you say it was?

A. Somewheres around 18 feet I would think it would be.

Q. Have you ever had occasion to take the depth there?

A. No, but the boat sticks you know, you think something is the matter; you think it is the bottom.

Q. Did you ever get stuck there?

A. Pretty near not quite but we may have rubbed something in the sides.

Q. You have rubbed on the sides?

A. The bilge.

Q. You spoke of the 12th Street Bridge, that is a center pier bridge there is it not?

A. Yes.

Q. The west draw is about 58 feet?

A. That is never used.

Q. That is never used and the east draw is 63 feet. That is the one that is used?

A. Yes.

Q. Do you remember prior to the Sanitary District Canal making those improvements what the draft permitted was or the depth of the river in the navigable part?

A. 16 feet.

Q. 16 feet. Since then how much is it?

A. Well, it is 18½ or 19; 18½ I guess is about as deep as they get.

Q. I I told you it was 20 feet, you would not want to gainsay that would you?

A. No, that may be.

Q. Do you know to what extent the river has been widened immediately north and south of the 12th Street Bridge since the Canal Project was undertaken?

A. North of 12th Street Bridge?

Q. Yes, north and south of the 12th Street Bridge?

A. I don't know of anything North of it. It was widened south of it.

Q. It has been widened south to 220 feet or about that?

A. Widened the river that much?

Q. No, so that it is 220?

A. No, that may be. It is not widened north of it.

Q. Not widened north?

A. No, not on the south side of the river; may be widened a little on the west side, where it is no good to anybody.

Q. If that center pier old bridge is removed and the water is at a depth of 20 feet so that you would get a span of between 160 and 180 feet, would that in your opinion improve navigation, to remove one of the obstacles you have been fearful about?

A. Yes, sir.

Q. Mr. Green, I show you a map entitled "Sanitary District of Chicago, map showing Chicago River improvement from 12th Street to 18th Street; scale 200 foot to one inch," and I draw your attention to that part of the plat which upon its face is indicated as 12th Street?

A. Yes.

Q. There appears there the center pier of the bridge at 12th Street, does there not?

A. Yes.

Q. I will ask you to look on the west side of the river?

A. Yes.

Q. And ask you to state whether from the track numbered 15 on lot 5, that is this point here (indicating) there has been any widening of the river to improve the conditions of navigation?

A. Yes, all that is there shown.

Q. All that is there shown colored a deep blue?

A. Yes.

Q. And that is carried all the way down here to the St. Charles Air Line Bridge, that is correct?

A. Yes.

Q. Has that removal of all of that adjoining soil improved the conditions of the navigation?

A. Greatly.

Q. And has reduced the dangers of navigation and the currents, hasn't it?

A. Yes.

Q. And then if the 12th Street center pier bridge is removed, and a newer type of bridge leaving a much larger span for navigation, for a 200 foot opening, if that is installed, that will still further greatly improve the conditions?

A. Yes, it will be all right.

Q. It will be all right. Now you spoke of the Pennsylvania Railroad Bridge at Stewart Avenue, I believe you said?

A. I guess that was it.

(A map was here identified and marked Exhibit for Identification 1, shown to Witness Green.)

Q. I will ask you to look Captain at the plat marked: "Sanitary District of Chicago, Map showing the Chicago River Improvement from 18th Street to Halsted," and I draw your attention to the point on the map indicated as 18th Street. That is removed is it not?

A. Yes.

Q. And a large bascule bridge with a wide opening there?
A. Yes.
Q. Has that improved navigation any at that point?
A. Yes.
Q. Greatly?
A. Yes. If they only would open the bridge, it would be all right.
Q. If someone would open the bridge. That is when the steamboats come down and blow the whistle, if the man in charge of the bridge would open the bridge, your troubles would be removed, is that it?
A. Yes. I ran into the draw of the bridge once. They did not open the bridge.
Q. You know the Sanitary District does not open and close bridges. You want to go over to the City Hall to raise that question. I want to draw your attention, going south or in a general direction southwest from the new bascule bridge at 18th Street to the part of the map indicated in dark blue, starting with the numbers, 1, 2, 3, 4, 5, opposite the words "Coal Dock"?
A. Yes.
Q. You remember that was a coal dock?
A. Yes.
Q. That has all been taken out?
A. Yes.
Q. That land or earth there has all been taken out down to the heavy blue line between the dark blue and the white passing through the letter "K" of the word "dock"? That has all been removed by the Sanitary District Canal?
A. Yes.
Q. Has that improved conditions?
A. Oh yes, greatly.
Q. Very much?
A. Yes.
Q. Then you get down to the Pennsylvania Railroad bridge which is at Stewart Avenue and immediately adjacent to the figures "48"?
A. Yes.
Q. Now the improvement that I have just drawn your attention to, by the removal of this dark blue dirt and earth, and the opening of this large bascule bridge, you haven't got the full benefit of it, on account of this Pennsylvania Railroad bridge?
A. That is right.

Q. If that Pennsylvania Railroad Bridge was out of there, then you would get the full benefit of it, wouldn't you?

A. Yes.

Q. And the Pennsylvania Bridge is a center pier bridge?

A. Yes.

Q. And as long as that is there, the widening of the river and the putting of this bascule bridge in has not helped you as much as it would otherwise?

A. No, that is right.

Q. When that Pennsylvania Bridge is out, and you get a wide open span bridge there, then you will be all right, won't you?

A. Yes.

Q. You know that the Government has condemned that Pennsylvania Bridge and is making them remove it; it is being removed now?

A. I believe it is. It has been many years.

Q. The Government moves very slowly. You want to go to Washington and make complaint about that.

A. (No response.)

(Map shown to witness was marked Exhibit Green Number 2.)

Q. Now, beyond the Pennsylvania Bridge going South and West, you have no trouble at all except at Halsted street, is that correct?

A. Yes.

Q. The depth of the river at Halsted street prior to the opening of the canal was much less than it is now, wasn't it?

A. Yes, I guess so.

Q. You have no trouble with the depths at Halsted street at all, do you? You have no trouble with the depths at Halsted street?

A. No.

Q. If that bridge that is now at Halsted street is widened, the open span is widened from 105 feet to 180 feet say, that will improve the conditions of navigation very materially, will it not?

A. Yes.

Q. You know that the river has been widened at Halsted street immediately north and south of the Halsted street Bridge?

A. Yes.

Q. Sir?

A. Yes, I know that.

Q. That widening has helped navigation, has it not?

A. Oh, yes.

Q. Now, beyond Halsted street, south and west, you have had no trouble at all?

A. Oh, yes, we have more or less trouble on account of the current.

Q. You have more or less trouble because you navigate a big ship?

A. More so where there is a current in a narrow place like the Chicago River.

Q. But no difficulty as compared with those you have indicated?

A. Oh, no.

Q. And those were ones that you encountered due to the narrowness of the river, often without a current, if there was no current, prior to the opening of the canal in 1900, were they not?

A. No, I could not say that.

Q. You had other difficulties, then, didn't you?

A. We had others, but many more now.

Q. You have more now?

A. Yes.

Q. But after these improvements were made, with the greater depth of water and with the wider openings of the bridges along the lines that I have indicated, navigation will have been greatly improved in the Chicago River?

A. It will help some.

Q. It will help materially, won't it?

A. Oh, yes, if you do not increase the current.

Q. Sir?

A. If you do not increase the current.

Q. The current that you have noticed in the river has been noticeable where the river was wide, most noticeable where the river was wide and where it suddenly narrowed? I mean narrowed into a pass or by-pass, which was made by the abuments of the bridges?

A. Yes.

Q. That is where you have noticed the heavy current?

A. Yes.

Q. Where you have spoken about the dangers of being jammed into piers or abutments of the bridges, that was at or about the place where the river was 200 feet wide or about 200 feet wide and suddenly was narrowed into a bridge opening of 90 or 100 feet, is that correct?

A. Yes.

Q. And thus created the dangers to navigation that you have referred to?
A. Yes.
Q. Sir?
A. Yes, some of them.
Q. The greater part of them, isn't that correct?
A. Yes.
Q. Captain, what depth do you navigate in the locks at the Soo?
A. About 18 feet, 18½.
Q. You are notified, it is a matter of public record to what depth you can load there?
A. Yes.
Q. What is the depth to which you can load to go through the Soo Canal?
A. Well, it is up to 19 feet, 19.6 I believe sometimes.
Q. Sometimes as low as 18.6?
A. Yes, less than 18.
Q. Sometimes less than 18? You have got to take that into consideration when you load from the Chicago River to go up the lakes?
A. Yes.
Q. Sir?
A. Yes.
Mr. Austrian: That is all.

Re-direct Examination by Mr. Hopkins.

Q. Those maps that were shown you, you don't know whether or not they are accurately made as to the amount of feet it shows, do you?
A. No, I could not say.
Q. You haven't checked up the maps or anything of that kind?
A. No.
Q. Do you happen to know the amount of tonnage that comes into the Chicago River now as compared with the time before the opening of the Drainage Canal?
Mr. Austrian: Objected to as incompetent, irrelevant and immaterial; has nothing to do with this case.
A. I don't know exactly. I know it is less.
Q. You know it is less?
A. Yes.
Q. Is there any other harbor on the Great Lakes where

you have as much difficulty with the current as you have in the Chicago River?

Mr. Austrian: Same objection.

A. No, it is the worst.

Re-cross Examination by Mr. Austrian.

Q. How about Port Huron, the Huron River, St. Clair River?

A. That is all right. That is wide, big, lots of room.

Q. Do you have any trouble there?

A. No.

Q. Captain, do you know that the class of small vessels has been affected by the building of great steamships by the steel trust and other combinations? Have you ever heard of that fact?

A. I have read something about it.

Q. Yes. Do you know that they have created and built vessels carrying from 10 and 12 to 15,000 tons capacity?

A. 12,000.

Q. 12,000 tons capacity. And can put as much freight in one of those as they could put in six boats of your capacity?

A. Yes.

Q. And that they have diverted that freight from the Chicago River to the places that they control the railroads to get cheaper carrying, have you ever heard anything about that?

Mr. Hopkins: I object to what he has heard.

Mr. Austrian: You asked him what he heard with reference to diversion of freight to the Chicago River.

Q. Have you heard any such talk as that?

A. No, but I have seen it of course.

Q. You have seen it and read about it?

A. Read about it.

Q. And the great steamships on the Great Lakes are now owned by the Pittsburg Steamship Company, aren't they, most of them?

A. Most of them, yes.

Q. And the Pittsburg Steamship Company, do you know who owns that?

A. I suppose the people in general.

Q. The Steel Corporation?

A. They own stock all over the country.

Q. Where do they carry their freight to?

A. To their furnaces wherever they have them.
Q. Where?
A. Well, it is in—
Q. Pittsburg?
A. From Erie to South Chicago.
Q. South Chicago. And they do not go through the river to go to their plants at South Chicago and Gary, do they?
A. No.
Q. They have built canals by which they can carry their steamers right in from the lake to their mills at Gary and South Chicago, right direct from the lake without going up any branch of the Chicago River, haven't they?
A. Yes.
Q. Sir?
A. Yes.
Q. And they used to have a plant on the south branch, a rolling mill plant or furnace plant on the south branch of the Chicago River and on the north branch of the Chicago River?
A. I know they had one up north but I didn't know they owned that south; I didn't know.
Q. There was a plant there?
A. There was a plant there, two plants.
Q. And the lake carriers used to bring the ore in a crude state, and the coal to operate those furnaces and plants into the south branch of the river and into the north branch of the river, didn't they?
A. Yes.
Q. But since the formation of the steel corporation, they have been closed down, haven't they?
A. Yes.
Q. And there was a big plant down at Bridgeport, too, that they used to operate before the steel corporation was formed?
A. That is what you had reference to?
Q. Yes.
A. They shut down before that time, I guess.
Q. Just before that?
A. Many years before that.
Q. These big steamers that are owned by the Pittsburg Steamship Company, they only carry, so far as you know they only carry ore for the United States Steel Corporation?
A. Yes.
Q. Not for anyone else?
A. No.

Q. They do not carry other kinds of freight so far as you know, do they?

A. Carry coal once in a while.

Q. They carry coal to their plants?

A. Well, to outsiders, too.

Q. Where?

A. Well, docks around the lakes, small docks, small boats.

Q. The small boats?

A. Yes, they carry coal around.

Q. That is when they carry coal up north, it is on the return trip that they carry the ore south?

A. Yes.

Q. Have you known of them to charter tonnage to carry the ore south?

A. Yes, they charter other boats, I know that.

Q. They charter other boats to carry the ore?

A. Yes.

Q. From the mines down?

A. Yes.

Q. Do you know or did you know of their sending any coal up with a chartered tonnage?

A. I don't know.

Q. Who asked you to come here to testify, captain?

A. Mr. Sullivan.

Q. Who is Mr. Sullivan?

A. He is vessel agent for the city.

Q. Who is he agent for?

A. He is agent for any boat he can get.

Q. But principally who is he the agent for?

A. I think for his own fleet of boats; he has got his own fleet of boats.

Q. Isn't he the agent for the Pittsburg Steamship Company?

A. Maybe; I don't know.

SVEND J. EMERSEN, resumed the stand and testified further, as follows:

Cross-Examination by Mr. Austrian.

Q. I understood you to say you had been a master mariner or captain for one year. Is that correct?

A. Yes, sir; but I have been captain off and on taking charge for a trip or so; but I do not include that in.

Q. And that you have navigated the Chicago River for three years?

A. Well, yes, off and on. That is not steady.

Q. Not steady?

A. No.

Q. When were those three years?

A. Oh, that was on an old schooner here 18 years ago.

Q. On a schooner 18 years ago?

A. Yes.

Q. Since 1896? That is 18 years ago?

A. Yes.

Q. Since 1896, how much, if at all, have you navigated the Chicago River?

A. Well, I navigated up and down then a couple of years, off and on.

Q. What years were they?

A. That was the two years after that.

Q. From 1896 to 1898, is that correct?

A. That is correct.

Q. That is before the canal was opened?

A. Before the canal was opened, yes. My experience than was not what it is now.

Q. You have more experience now than then?

A. Yes.

Q. Certainly. You and I are about the same age, about 21?

A. About that.

Q. This boat you had occasion to run up and down the Chicago River from 1896 to 1898, was that a steam craft or sailing craft?

A. No, a barge towed by steamboat.

Q. Towed by steamboat?

A. It was towed by steamboat.

Q. The conditions in the Chicago River in 1896 and 1898 when you were there, you don't remember very distinctly?

A. No.

Q. You don't remember the conditions very well?

A. Not very well, no.

Q. Do you remember the smell?

A. Indeed I do. I don't remember any current though.

Q. Your mind is on current; my mind is on smells just now. So you just direct your mind where mine is; it is easier to remember. I am asking you, Mr. Witness: Do you remember the smell?

A. Yes, I do.

Q. You don't remember any current?
A. No, sir.
Q. You have not been up here when there were any freshets or storms?
A. No.
Q. You haven't any recollection about any of those?
A. No, I haven't any.
Q. Of course I only want to know what you remember?
A. Yes.
Q. I am not trying to trip you, and you are not trying to trip me?
A. That would not do.
Q. Mr. Emerson, I understood you to say on your direct examination that in operating on the Chicago River in the last year—and I understand that is the only time you have operated since 1898?
A. Yes, since 1898.
Q. —you have noticed a current that went at times from 2½ to 3 miles an hour. Is that correct?
A. Yes, sir.
Q. Where was that current noticeable?
A. Well one time I came in here last summer.
Q. I mean at what place in the river?
A. I was going to give you, down to the pier, down to the coal dock down here at West Pier, or South Pier, these two piers.
Q. What bridge?
A. That is before you get around to the mouth of the river.
Q. It is east of the bridges is it?
A. Yes, outside the bridges altogether.
Q. East of the bridges?
A. Yes, east of the bridges.
Q. You saw a current through there?
A. Quite a current there one time.
Q. That is at one time. Where have you noticed this heavy current that you speak of that is from 2½ to 3 miles an hour?
A. There is one place down there at the coal dock; and Jackson, and Adams, 12th street and also Halsted street.
Q. At the coal dock you refer to, the river is about 300 feet wide, isn't it?
A. Yes, I guess it is, probably a little better than that.
Q. A little wider. You read those names of the places

you noticed the current from a little memorandum book just now, didn't you?

A. Yes.

Q. When did you write those in the memorandum book?

A. In my log book on the steamboat.

Q. In your log book on the steamboat?

A. Furthermore, because I do not recollect the names of those bridges. All I have to do when I operate my steamboat is to watch my boat. I don't take notice of them bridges, but by inquiring what is the name, so and so bridge.

Q. When did you write those names down?

A. I wrote them down to-day.

Q. You wrote them down to-day?

A. Yes, so I could tell you where the places were.

Q. You told Mr. Hopkins where they were before you told me.

A. I told him that yesterday.

Q. I mean to-day, you told him right here in this room.

A. Yes.

Q. That is all right.

A. I had them down then.

Q. When did you write them down, yesterday or the day before?

A. I wrote them down to-day.

Q. You wrote them down to-day? I thought you said you wrote them down yesterday so you could tell me?

A. To-day I told you?

Q. You told me to-day?

A. Yes.

Q. You wrote them down to-day?

A. Yes.

Q. Who came to see you about testifying in this case, or who asked you to come here?

A. Captain D. Sullivan.

Q. The same Mr. Sullivan that the previous witness referred to?

A. Yes.

Q. Did you talk to him about your testimony?

A. Why he got the testimony from me last summer.

Q. You talked about your testimony to him then, did you?

A. Well, different places where I had any troubles, yes.

Q. Did you write it down?

A. Why, he got our record over there, yes.

Q. He got a statement from you?

A. Yes. Of course, you must remember we don't write to

the office how much current we have here, how much current there. That is to be carried by ourselves.

Q. You have to carry that in your mind?

A. Yes.

Q. You have no independent recollection, have you, of any particular time of month or day in the month or month in the year that you saw this current of 2½ or 3 miles?

A. Yes, we came up here in June.

Q. Last year?

A. 1913. And I have been up here in August; and I was up here last November; the first part of December, rather.

Q. Then you were here in June, in August and the first part of December last year?

A. Yes, December.

Q. Those were the three times you were in the Chicago River last year?

A. Yes.

Q. That is you made three trips into the river?

A. Yes.

Q. In June where did you go; where did you land your boat?

A. 35th street.

Q. In August where did you land your boat?

A. 35th street.

Q. In December where did you land your boat?

A. Lehigh Coal Dock between North avenue and Fullerton, I think, aboue North avenue.

Q. When you went up to the Lehigh Coal Dock, did you strike any currents there?

A. Not after I got through the forks, I did not, through Kedzie street.

Q. You found no currents in the North branch?

A. No.

Q. Then the only two trips you had since 1898 in the Chicago River, in the South Branch, were in June and August of 1912?

A. 1913.

Q. I mean 1913?

A. Yes.

Q. And the observations concerning which you have testified were made on those two trips?

A. Yes, sir.

Q. And that is all you know about it, isn't it?

A. That is about all I know about it.

Mr. Austrian: That is all.

Mr. Hopkins: That is all.

J. P. MINSKEY, resumed the stand and testified further, as follows:

Cross-Examination by Mr. Austrian.

Q. What are your initials?
A. J. P.
Q. Mr. Minskey, I understood you to say that two years ago this winter you were in charge of some boats that were operating or stationed on the Chicago River, is that correct?
A. Well, yes, I had charge of the boats, but we were not what you call operating on the river. We were holding them here for storage; that is we were holding grain for storage.
Q. That was in 1912?
A. Yes.
Q. There was supposed to be a corner in the grain market in 1912?
A. I guess you might call it that, for they put the oats in some of these boats for about 35 cents, and sold them out for 80 in the spring.
Q. There was a shortage of warehousing space?
A. Shortage of warehousing.
Q. So those who had purchased the grain, the oats whichever it was, had it brought here, and instead of putting it in warehouses they put it into empty bottomry.
A. Put into these vessels.
Q. And those vessels tied up at certain docks along the river?
A. All along the—
Q. The South Branch?
A. Both branches.
Q. South and North Branch?
A. Mostly in the North Branch.
Q. There were some 15 vessels in number, weren't there?
A. Why, I think so.
Q. I mean under your charge or supervision?
A. Yes.
Q. That is instead of having the vessels earn no money after the close of navigation, your company or your associates had an opportunity of leasing the bottomry for warehousing purposes to store grain; and they took advantage of that and stored them in the Chicago River?
A. Yes, the season was rather poor in the coarse freight trade. The company I was with at the time were not con-

nected with the Iron Company so that—and coarse freight being very scarce, the boats were chartered in the last of August and September and put into this storage here and South Chicago.

Q. When you say that your line was not affiliated with any iron industry or ore industry, you mean it did not carry any of the ores from the mines down to South Chicago or to the Pittsburg industries, and hence the season was poor. Is that correct?

A. Yes.

Q. The Pittsburg Steamship Companies' boats were operating as usual that summer?

A. I think so; not alone the Pittsburg, but there was a good many others that is connected with the iron business, that is in the same—

Q. The observations that you made with reference to the condition along the Chicago River you made principally while you were in charge of those 15 boats?

A. Yes.

Q. During the winter of 1912?

A. Yes.

Q. Navigation at that time was closed on the river?

A. Well, not when I began.

Q. You began in September, wasn't it?

A. Yes, last of August.

Q. Last of August?

A. And September, the boats—I think my boat ran that year 72 days, and we started in the early part, June, maybe and ran 72 days, and then I was sent here and took charge of these boats.

Q. Do you remember when your boat was taken off?

A. Just the day?

Q. Well, approximately the day?

A. Oh, it was in August, the last of August that I was laid up.

Q. And did you immediately come here?

A. Immediately came here.

Q. And the boats were all tied up?

A. Some were and some were not.

Q. When did you begin to make observations as to the condition of the Chicago River?

A. As soon as I took charge of them.

Q. Where, at what point in the river did you take charge?

A. I had charge of all of them.

Q. Did you travel around from one boat to another?

A. I traveled around from one boat to another every day; went aboard every boat every day.

Q. You were a sort of inspector, were you not?

A. Yes.

Q. To see the condition of the grain?

A. See that the grain was taken care of.

Q. Kept dry?

A. And see the boats was not damaged, or if there was damage who done it and what the circumstances was.

Q. It will be necessary for you to tell us where your boats were located.

A. I could not locate them all; we moved them so many times I could not do that. We had one that laid a long time right above 18th Street Bridge; one laid—

Q. Is that where you made the principal observations?

A. Well, as much as any probably there.

Q. Right above the 18th Street Bridge?

A. Between 18th Street and the Pennsylvania Bridge.

Q. Between 18th Street Bridge and the Pennsylvania Bridge?

A. Yes.

Q. Where else did you make the observations you have testified to principally? I don't care what you saw walking across the bridge, but you have testified as to certain conditions that you observed at the places where these boats were located.

A. I said—

Q. Tell us the next one?

A. I think you are mistaken about that.

Q. I may be wrong. I am not infallible; I am not like the Government.

A. The damage, I think the boat that laid there got the most damage maybe of any.

Q. All right.

A. And another one that laid below the bridge, and maybe a length below the bridge.

Q. That is below the 18th Street Bridge?

A. Yes, she had a good many damages. She was between, about half way between the railroad bridge and 18th street, below the bridge there.

Q. That is north, isn't it?

A. Well yes, north of 18th street.

Q. North of 18th?

A. That 16th Street bridge there is a railroad bridge. We

laid,—one boat laid this side of the bridge and the other laid the other, and I think those two boats got more damage than any other that I had, that I was looking after. You see the river crooked and the flow made a bend you know, and rubbed you.

Q. Now Captain, do you know how these damages occurred, did you see it?

A. No, I don't think I saw one.

Q. You didn't see any damage to the boat?

A. Only saw the damage.

Q. Saw the result?

A. Saw the damage but didn't see the collision.

Q. Didn't see the collision?

A. No, it was boats rubbed them.

Q. You didn't see the collision, or how the damage occurred upon any boat that you had?

A. Oh yes, I did.

Q. Tell us one?

A. Well, the steamer Lake Shore, when we were jammed in the Pennsylvania bridge.

Q. The steamer Lake Shore?

A. We have a law suit on her that we haven't got settled yet.

Q. The steamship Lake Shore, when you were jammed—

A. We were trying to get through it at the time.

Q. At the Pennsylvania bridge?

A. Yes, and could not.

Q. At the Pennsylvania Bridge?

A. Yes.

Q. Who did you sue there?

A. I think the company sued the Tug Company.

Q. The Tug Company was the company that was hauling the boat?

A. Towing the boat.

Q. You sued them for negligence, didn't you?

A. I think so.

Q. Because they had not drawn you through properly, is that right?

A. Well, because we received the damage in going through the bridge, or trying to get through the bridge.

Q. Because you contended they operated the tow negligently or carelessly, is that right?

A. Well, as far as I was concerned, I didn't think it was carelessly.

Q. Still you sued them?
A. Well, the damage came there and our company wanted to recover if they can.
Q. Why didn't you sue the Sanitary District?
A. What?
Q. Why didn't you sue the Sanitary District?
A. I give it up, partner. I ain't a lawyer for the firm and won't boss that, and I don't know. If I was the lawyer for the firm, maybe I would have sued the Sanitary District, but as I was not—
Q. Did you collide with one of the Rock Island boats?
A. With what?
Q. With one of the Rock Island boats?
A. Rock Island boat?
Q. Yes?
A. Have they got any boats?
Q. I dont' know. I am asking you.
A. Not that I know of.
Q. Did you collide with any boat in this current you have just testified to at the Pennsylvania Bridge?
A. No.
Q. You just collided with the bridge?
A. Just collided with the—
Q. With the abutment?
A. With the approach of the bridge.
Q. It would not get out of your way?
A. It would not get out of the way.
Q. Now then, did you see any other accident, that you have referred to?
A. Yes, at the time I was trying to get the Neptune past Washington Street Bridge, I had ahold of her and saw her run into the approach to the Lake Street Bridge.
Q. That is the occurrence of this Neptune damage; that is the occurrence that you speak of when you had difficulty getting over Washington Street?
A. Yes.
Q. They had been doing some repair work in the river at Washington Street?
A. Yes, they were—
Q. Sinking a caisson, weren't they?
A. Putting a foundation in for the bascule bridge.
Q. There was a lot of work going on there, and you had difficulty in getting through?
A. We tried to get over and that is the place I had four

tugs on the job and they could not get her over, there was so much current.

Q. You finally did get her over?

A. They shut down the canal for us and the next day we got over and then we did the damage on the bridge.

Q. You got over so fast that you went two whole blocks?

A. We went over slow for a long time. When she did start, the tugs didn't stop quick enough, stop pulling quick enough. We were going pretty fast.

Q. There was no current there at all that day?

A. Oh yes, rather strong current.

Q. Strong current?

A. Yes.

Q. The current was against you?

A. The current was against us.

Q. Still you got over the Washington Street Bridge, and you went from Washington to Lake Street, bumped into Lake Street and that was all on account of the Sanitary District Canal being open?

A. Now as I told you, we went slowly past the bridge, but as she passed it, after she got by it they didn't stop pulling quick enough and we did the damage.

Q. Do you blame that on the Sanitary District?

A. We blamed it on the tug and we were trying to recover from the tug.

Q. You are trying to recover for what happened on that occasion?

A. If I had thought, I would have put a letter in my pocket and showed it to you.

Q. If the current had not been there, if it had been down the river you would have gone still faster?

A. We would not have done any damage because we would have been going slow.

Q. You would have been going slow?

A. Yes.

Q. You sued the Tug Company for that negligence?

A. I didn't sue.

Q. The company did?

A. The company is suing on that.

Q. With the exception of the Lake Shore incident that you sued the Tug Company for and the Neptune incident you sued the Tug Company for, you observed injuries to your boats occasioned at the 18th Street and Pennsylvania Railroad

bridge, and immediately north of 18th Street. Is that correct?

A. Yes.

Q. Now Captain, did you ever navigate the Chicago River?

A. Did I ever navigate it?

Q. Yes?

A. Yes, sir.

Q. As part of your business I mean?

A. I have not for 25 years. Previous to that 25 years, before, I navigated it very often.

Q. I must admit the soft impeachment, that is too late for me. Captain, I show you the map which has been identified as "Witness Green Number 2," and point out to you 18th Street as indicated upon this map, so labeled. Can you see Captain without your glasses?

A. I could not see it without my glasses, boy.

Q. All right, I am with you. That (indicating) is 18th Street?

A. Yes, sir.

Q. Here (indicating) is the Pennsylvania Bridge?

A. Yes.

Q. That is indicated?

A. That is here.

Q. Yes, right there. You say your boat was lying between 18th Street—

A. And here.

Q. That is your boat was lying on the West side of the river?

A. On the South.

Q. This is West?

A. Oh, I thought this was the river.

Q. This (indicating) is the river.

A. I had a boat lying here (indicating), on this side.

Q. That has been widened. The river is there (indicating) now. This soil has all been taken out; the deep blue is all out.

A. That may be, yes.

Q. There (indicating) is the river bank. This heavy blue line is the river bank.

A. When did they take this out? It seems to me there was a crook right there (indicating) and we were right down here (indicating).

Q. That is the crook?

A. It was more than that there, boy.

Q. They have taken that out—

A. The last two years?

Q. Oh no, it has been taken out many years ago, the deep blue has been taken out many years ago.

A. All right.

Q. Since the canal was opened.

A. I won't dispute you, boy.

Q. That is a fact.

A. My recollection of the river was a sharp bend, and our stern stuck just a little by it, and there is no center in this.

Q. That is out too?

A. And they came in and butted us right there. I had another one right over in here.

Q. You had one on the East side and one on the West side?

A. I had to move away. I didn't leave her there only a week and I had to move her.

Q. When did this accident occur on the West side?

A. Oh, I had a half a dozen ones.

Q. When did the accident you are talking about occur to the boat on the West side?

A. The bruise at the dock?

Q. Yes, on the West side of the river, on this side of the river, the West side?

A. Why it was along in the river; I could not tell you; or early in the fall. I had five or six damages on this one here (indicating).

Q. That is on the West side?

A. It is.

Q. That is West; West is over there, East here, North there and South here.

A. East over there?

Q. Yes. I want to know when the damage occurred to the boat that was lying on the West side?

A. Oh didn't have one there only about a week.

Q. When did the accident occur, or the damage occur to the boat on the West side?

A. I said I didn't have one there but a little while. I don't know, I said we had any accident on the one on the West side. I said they didn't leave her there but a few days, less than a week and then took her back, loaded her to an elevator, steamed her up there out of the way.

Q. Now Captain—

A. I had four or five accidents on this boat, while she was lying here (indicating).

Q. On the West side or the East side?

A. The East side of the river.

Q. That is on this side (indicating). Here is the Indiana elevator right here.

A. Well, that is all right, yes.

Q. You laid her up near the elevator, did you?

A. This is the elevator they tore down, didn't they?

Q. I don't know.

A. This is above the 18th Street, South of 18th Street?

Q. This is South of 18th Street.

A. Yes sir, south.

Q. There is 18th Street, there is the Pennsylvania Bridge.

A. She was laying where this old elevator was and laid there for—she laid there for three months.

Q. Three months?

A. Yes, and in the time—

Q. From August to September?

A. From probably September sometime up until in January when we moved her, when we tried to—

Q. About January?

A. Yes.

Q. And she had several bumps?

A. She had several bumps there, yes.

Q. Was there any ice in the river?

A. Oh, not so very much.

Q. In 1912?

A. Oh yes, there was drift ice in the river but it never froze up so but what they could move boats.

Q. There was drift ice in the river?

A. There was drift ice in the river all winter.

Q. And there were boats navigating in the river beyond and beside your boat you had tied up at the Indiana Avenue elevator?

A. The damages all came on this boat before the close of navigation.

Q. Before that?

A. I think so.

Q. You don't know whether they did or not, do you Captain?

A. Yes, I do.

Q. You know these ten or twelve damages you got all came before navigation closed in 1912?

A. Well now I don't think all of them came because some we got moving them ourselves, so we were moving them later

in the year; but the damages came in the fall, while the boats were running, before navigation shut down.

Q. The damages came while the boats were running?

A. Not these boats were not.

Q. But other boats in the river?

A. Yes.

Q. You know boats were running in the river all winter that year, weren't they?

A. Well, not very much.

Q. Some?

A. Oh yes, some, of course, but then they are smaller boats and don't cut so much figure.

Q. Then I want you to tell me Captain when that boat that was lying at the Indiana elevator was damaged, and how often it was damaged and how it was damaged?

A. Well she had a damage forward that came, I could not tell you the boats that damaged that; and she had four damages on her after end.

Q. Four?

A. Yes.

Q. Within what period of time?

A. Just hit against the rail and pushed them in and broke the stanchions along from the mid ship's side.

Q. Within what time did these four damages occur?

A. Within four months, three months I should say.

Q. Within a period of three months?

A. Yes.

Q. That is three months intervened between the first collision—

A. I should think she was lying there three months.

Q. What space of time intervened between the first damage to her and the last damage to her, while lying at the Indiana Avenue elevator?

A. I could not tell that without going to the Company and getting the damage from each boat.

Q. I am only talking about the one that was lying at the Indiana elevator.

A. Yes, I know; that boat laid there from the time I took charge of her until she was unloaded sometime in the winter.

Q. You said about January. You said she laid there from September to January?

A. I should think it was somewhere about January, maybe later than January.

Q. You said she was damaged four times while lying there?

A. She was damaged while lying there.

Q. Four times?

A. I think so.

Q. I am asking you now what period of time elapsed between the first damage and the last damage, while she was lying there?

A. I think you are asking something I could not tell you without getting my accounts from the company.

Q. Your reports from the company?

A. Yes, my reports that I sent into the company.

Q. Where is your company's office, Captain?

A. It is in Cleveland.

Q. Those reports that you sent into the company, you retained no copies of?

A. No, the company went into bankruptcy. They were under a receiver's hands at this time.

Q. They were not connected with the Pittsburg Steamship Company?

A. And they were sold out a year ago in February; all the boats were, and the company has three little boats left.

Q. It would be rather hard to get your reports now?

A. I should rather think so. I had this letter from these—from the attorneys, and wanted me to look them up some witnesses, some more witnesses than I had given, and send them.

Q. Yes, but Captain you remember—

A. In this same ship.

Q. You remember visiting the ship every day?

A. Every day.

Q. Were those four accidents within a period of 30 days?

A. Oh no, it was longer than that.

Q. Within a period of 60 or 90 days?

A. Yes, it won't more than that.

Q. You would say between the 1st and the last?

A. Yes.

Q. Must have been 90 days elapsed?

A. Yes.

Q. And that boat was not put there until about the first day of September?

A. It was in September, I think.

Q. All right, September you think. So the last accident must have occurred in or about the first day of January?

A. Somewhere along in the winter, first of the winter.

Q. Or in December, instead of January?

A. Oh my dear boy, that is two years ago you know. I have so many of those accidents that same winter that to define just what time an accident happened on one of the boats—

Q. I am not asking you to define it; I am only asking what space of time intervened between the first and the last accident to the boat at the elevator?

A. I should think it would be at least three months probably.

Q. Three months; then that last accident must have occurred after navigation closed?

A. Practically probably.

Q. Navigation didn't stay open until December that year, did it?

A. Well, I guess it never closes before December 1st.

Q. Never does?

A. No, the insurance lasts until the 1st of December.

Q. 10th of December.

A. 10th of December.

Q. Captain, how long after you put the boat there did you have your first accident?

A. I don't think it was only a few days. You see it is almost impossible to find places in the South Branch to tie up the boats.

Q. Because the boat is about 40 feet wide, one of the big boats, at least, 40 foot beam?

A. 52 foot beam.

Q. 52 foot beam. That is a pretty wide boat to block up a river with?

A. Yes, and we were laying in a bad place there, but we could not find another place. They were tearing down this elevator at the time.

Q. You were lying in a bad place?

A. We were lying close to 18th Street bridge, close to the bridge, and then afterwards backed up further, and it was impossible to find places to lay those boats.

Q. You don't consider that because you had accidents lying at a bad spot like that in the river, that that was a very unusual thing do you, Captain?

A. Some day you would think it was because it was right in a hollow there, but they had to turn and make this railroad bridge just above this bridge (indicating), turn and make that and then the other way, so that—

Q. You were in a jammed place?

A. In a jammed place.

Q. If you were going to pick out a spot to lay a boat up three months in the Chicago River, that would have been one of the last places you would pick?

A. If we had to lay up in the South Branch, I don't know one more spot.

Q. You were right between the 18th Street Bridge and the Pennsylvania Railroad Bridge?

A. Yes.

Q. And the Pennsylvania Bridge was a center pier bridge and there was a very severe turn immediately south of the 18th Street bridge? That is correct?

A. Yes.

Q. A sharp turn between the two bridges and you were lying on the low side, but still the sharp turn was there?

A. Yes.

Q. And the boats went through the North Draw of the Pittsburg Bridge, didn't they?

A. Yes.

Q. So that made it a very delicate spot to lay a boat up?

A. Yes. You could not go through the other draw.

Q. You could not go through the other draw. You know the Government has ordered the Pennsylvania Railroad to remove that bridge, don't you?

A. Well, they were removing it that winter.

Q. They were removing it that winter?

A. They started to build the—

Q. The new bridge?

A. The new bridge, that winter.

Q. That clogged up the river some too?

A. Yes.

Q. That made it still worse?

A. That is one thing why we could not get through because they blocked it up, made so much current they could not get through. We laid just above the bridge with this same ship some four or five days and there was so much current we could not get tugs enough to pull her through.

Q. That heavy current was due to the Pennsylvania Railroad clogging up the—

A. It was due to the Drainage Canal in the first place.

Q. But increased by their closing up one-half of the river at that point and building the new bridge?

A. Part of one-half.

Q. Part of one-half?

A. Yes. You know I have nothing against the Drainage Canal.

Q. You think it is a good thing, don't you?

A. How?

Q. You think it is a good thing?

A. Why—

Mr. Hopkins: Objected to.

A. It is a good thing, sure, if they don't make so much current that they spoil our waterway.

Q. You are more interested in that than anything else?

A. Than I am in anything else.

Q. That is your livelihood?

A. Yes. For instance the Cuyahoga River at Cleveland is a much crookeder river than our South Branch. It is a much narrower river. At the same time we have no difficulty in going up that even as far as our Santa Fe elevator would be here. We go up there to the upper furnaces with boats that are 500 feet long. I can't say without trouble, because it is, but we can go slow; we can get up without doing damage.

Q. Now Captain, just stop a moment: I understood you to say that sometimes you saw a terrible current in the Chicago River, regular rapid.

A. If you would have been on the Lake Shore when we were trying to get through that bridge, you would have seen it yourself.

Q. But that is the Washington Street accident?

A. No—

Q. The Pennsylvania?

A. Yes.

Q. That is where they had clogged up the river in building the bridge. They built a dam there, didn't they?

A. Well, I don't know as it was a dam.

Q. It was a cofferdam?

A. It was narrow and when the boat got into it, it increased it.

Q. Still narrower

A. So it would run by just like this (illustrating).

Q. The time you refer to is when they were re-constructing the Pennsylvania Railroad Bridge south of 18th Street, is that right?

A. They had just started it.

Q. Just started, and they had built a cofferdam in the south draw of the Pennsylvania Bridge, hadn't they?

A. Yes, they had just started it.
Q. To build the cofferdam?
A. Just started to build it that winter.
Q. And then your boat came in to the other draw?
A. Came into the north draw.
Q. Into the North draw, and your boat was 52 feet beam?
A. Yes.
Q. The center piers of the bridge were there in the middle of the stream?
A. Yes.
Q. And the cofferdam was in the west of the stream, so there was not very much space left in the river to carry the water, was there?
A. Well, there was not so very much, but we got all the way we could get with four tugs on the boat.
Q. Answer my question please. There was not very much—
A. I beg your pardon; I meant to do it.
Q. There was not very much space left in the river when your boat got in that draw?
A. No.
Q. This is the place you saw the current you testified to on your direct examination?
A. Sure, that I said it was going ten miles an hour.
Q. Yes?
A. I think it was going every inch of it.
Q. Of course if they built a dam across the river at any spot in the river and left not more than 25 or 30 feet, you would see a very heavy current there too?
A. I guess you would.
Q. Captain, you said it was very difficult to get a tying up place in the south branch of the Chicago River that winter. Why didn't you tie up in the north branch?
A. It costs money where you load a boat away out at the Santa Fe elevator to turn around and tow her up to the north branch to get a place to lay it; costs quite a penny.
Q. There were no elevators in the north branch?
A. How?
Q. There were no loading places in the north branch?
A. Yes.
Q. Did you load any?
A. We had three or four elevators there that we loaded boats.
Q. In the North Branch, did you load them there?
A. Yes, loaded them in the North Branch.

Q. You had no trouble in the North Branch?
A. No.
Q. But the rest of the boats—
A. What boats we had in the South Branch, we had a lot of trouble.
Q. You tied them up in the South Branch?
A. We tied them sometimes. We didn't tie them all. When we loaded close down this way, where we could get them to a safer place, we took them there.
Q. You spoke about an accident at the 18th Street and Pennsylvania Bridge other than this one above 18th Street. You had a boat between 16th and 18th Street Bridge?
A. Yes, she was on the lower side of the river.
Q. On the east side?
A. On the east side, yes.
Q. I show you Green's Exhibit 1, Exhibit for Identification. This is 18th Street as indicated in print. And here is the 16th Street bridge indicated on the map.
A. Yes.
Q. That is a railroad bridge (indicating).
A. This is the east side.
Q. This is the east side, the right side the way you are looking is the east side. Will you indicate where you had that boat tied up?
A. (Indicating).
Q. This is 16th; this is 18th?
A. Tied up right along here (indicating).
Q. You had that boat tied up right at the bend—
A. It is very near straight here and just—
Q. That has been cut off between here somewhere?
A. This is wider now.
Q. Yes. This is where the docking used to be; here (indicating) is where it is now.
A. We had her lying here (indicating) for some time.
Q. That is you had her between 16th and 18th Street?
A. Yes. She didn't come right down to that slip. Right here (indicating) is a railroad dock where they handle package freight and we were close to that, a little warehouse along in there, we were close to that and laid up along this way.
Q. That was right in the bend of the river between 16th and 18th Street?
A. The bend here. Very little of this river but what you will find bends in, 300 or 400 feet—
Q. That was in the bend between 16th and 18th Streets?

A. Yes, on this side.

Q. On the East side?

A. Yes.

Q. How many accidents did you have there while your boat was tied up?

A. I think that boat had two accidents there.

Q. That was due to the fact that some boat bumped into you and scraped you?

A. Bumped into us and rubbed us; one hit us on this bow here (indicating), and one bumped her on the stern.

Q. You didn't see either of those accidents? You don't know how they occurred?

A. I didn't see either. All I know is what the ship keeper told me when I came up there. And then I seen one of the men that did the damage and he came down there with some one, settled it, same as fixed up.

Q. The 16th Street Bridge, that is a center pier bridge?

A. Yes, sir.

Q. That has not yet been changed. They only used the draw on the East side, didn't they?

A. They used both sides of that.

Q. For the big vessels?

A. Why I should think so. I never have used it. We always go down this side (indicating); but it seems to me there is room enough.

Q. The vessels you have seen go down there always went down the east side?

A. The vessels I have seen go down there always went down the east side.

Q. Coming from the east side then they have to necessarily approach close to your vessel, wouldn't they?

A. Well, there is plenty of room there, if it was not for the current.

Q. They would have to approach near your vessel, wouldn't they?

A. Oh yes, yes.

Q. Did Sullivan talk to you about testifying in this case?

A. How?

Q. Did Mr. Sullivan talk to you about testifying in this case?

A. No, sir.

Q. Who asked you to come here?

A. Who asked me to come? I had a letter from the District Attorney asking me to come.

Q. Did anyone speak to you—

A. He said Captain Sullivan—
Q. Had given him your name?
A. Had given him my name, though I hadn't spoken to anybody.
Mr. Austrian: That is all.
Adjourned subject to notice.

Deposition of witness taken before the Commissioner on the 10th day of April, 1914, at 3:00 P. M. at Room 606 Federal Building.

Present:
Mr. Albert L. Hopkins,
On behalf of the Government.
Mr. Edmund D. Adcock, and
Mr. Alfred S. Austrian,
On behalf of the Sanitary District.

JOHN F. HAYFORD, a witness called in rebuttal on behalf of the Government, was first duly sworn and testified as follows:

Direct Examination by Mr. Hopkins.

Q. State your name?
A. John F. Hayford.
Q. Where do you live Mr. Hayford?
A. Evanston, Illinois.
Q. What is your business or profession?
A. Civil Engineer and Director of the College of Engineering, Northwestern University.
Q. How long have you been connected with the Northwestern University in that capacity?
A. Since 1909.
Q. Before that time, what was your work or business?
A. From 1898 to 1909, I was in the Coast and Geodetic Survey, Government Survey, first as expert computer and Geodesist two years and then 1900 to 1909, as an inspector of geodetic work and chief of the computing division.
Q. Where did you have your training, and what was your training, education and so on?
A. Cornell University, graduated with degree of civil engineer.
Q. When, what year?
A. 1889.

Q. What was your work from 1889 to 1898?

A. From 1889 to 1895, I was connected with the Coast and Geodetic Survey as computer, and then on the field force, detailed two of those years on the survey of the boundary between the United States and Mexico.

Q. From 1895 to 1898 what were you doing?

A. During those years I was instructor in civil engineering in Cornell University, teaching mainly mechanics, surveying and astronomy.

Q. A little more in detail, what has been the nature of your work during the last 11 years, or during the 11 years you have been in the Geodetic Survey work?

A. During those 11 years, 1898 to 1909, I was in charge of the triangulation and leveling and the astronomical work, both in the field and the office. That is I was responsible for the method used in the field work, for seeing that those methods were properly carried out as to the general conduct of the field work in those lines, and responsible also for all the office work, the computations of those same groups of observations.

Q. Were you in charge of or did you have anything to do with the reduction of observations?

A. Yes, during those years in charge of the office work, was of course primarily in charge of the computations; had a force there which varied from 15 to 20 engaged entirely in computations in those classes of work.

Q. What is the geodetic work of the United States Coast and Geodetic Survey, and what is its extent?

A. So far as the interior of the United States is concerned, the survey, it is the precise leveling of the whole country, carries the astronomic work throughout the whole of the United States. Then for all of the Coasts under the jurisdiction of the United States, the Coast Survey has the making of the charts; including in the making of the charts everything from the surveys themselves through to the printing of the chart. That is for all coasts under the jurisdiction of the United States. Of course not including the Great Lakes in that.

Q. Tell just what you did Mr. Hayford?

A. It was land work, and of course the triangulation was for the control of the charting work which is charting of water as well as land; but the work itself was land work primarily.

Q. I understand that you did some field work, didn't you?

A. Yes, sir, during those 11 years I was responsible both

for the field and the office work in those lands. I was responsible from the beginning of the making of the plans of the field work to the publication of the results. That involved getting out engineering work, seeing how the work was done; being entirely familiar with the field and office, I was as much responsible for the field work as the office work in those lines. That is that was triangulation, leveling and astronomical work.

Mr. Adcock: Q. The astronomical work was to locate yourself as to stars where you were working?

A. Yes, and getting the true directions.

Mr. Hopkins: Just following that, what was the purpose and what were the duties of the Coast and Geodetic Survey?

A. To furnish, so far as the coast work is concerned, to furnish reliable charts for the benefit of navigation, to make navigation safe; and so far as it is part of the interior work of the United States, so far as that is concerned, it is to help furnish the framework on which reliable maps of the whole country may be drawn. That is it is responsible, as far as the interior is concerned, for the framework only, the triangulation and the precise leveling. On the coast work of the Survey, it has to do the whole thing, furnish the detailed chart.

Mr. Adcock: That is on land or water?

A. Water; and the land near the water, in sight of the navigator from his ship; the fringe of land along the coast.

Q It is the location of the shore, in other words?

A. The shore, and such portions back of the shore as may be seen from the deck of the vessel and therefore might be needed by the navigator.

Mr. Hopkins: Q. In connection with that, did you have anything to do with water levels, observing water levels, tides and things of that kind?

A. Yes. Of course precise leveling is started from tidal observations to get the connection with sea level; also it happens that a necessary part of the precise leveling of the United States was the connection with the water levels through the Great Lakes; and therefore I was brought in touch with the water levels through the lakes, which were used as a part, in reality, of the precise level net.

Q. You have had a good deal of experience have you not with the reduction of observations made by engineers in the field?

A. Yes, sir, throughout that whole service. You see the office part of the work done under my direction was largely just that matter of reducing the observations, finding the

correct conclusions from the observations which had been made by the field parties.

Q. Is there any difference between the way the computations of field work are made in that kind of work and those made by hydraulic engineers in the measurements of rivers?

A. Why the general methods, of course, are the same for the computations. The details of the methods necessarily differ with the material that is being handled.

Q. You went directly to the Northwestern University when you left the Coast and Geodetic Work?

A. I did, yes.

Q. What is your work at Northwestern?

A. It is mainly administrative work, as director. I have a teaching schedule which is less than one-third of the regular schedule, so it is mainly administrative work.

Q. Do you have any outside work?

A. I have during those years been doing other outside things, at the same time that I was doing the work as director.

Q Have you had any special work during this time, in addition to the experience you have already given?

A. This is during the time I have been at Northwestern?

Q. Well, during the whole time.

A. Well, in those years at Northwestern, I in the first place, for two of the years, 1909 to 1911, I was still continuing the computations and writing for the Coast and Geodetic Survey, completing the work that had been begun while I was in their service. Then from October 11, to July 13, I was a member of the Commission of Engineers on the Costa Rica-Panama Boundary Arbitration.

Q. By whom were you selected?

A. Appointed by the Honorable E. D. White, Chief Justice of the United States. And the third piece of work I did during those same years, work still in progress, is an investigation of the evaporation and the stream flow, made under a grant from the Carnegie Institution of Washington.

Q. That is evaporation any particular place?

A. The purpose of the investigation is to determine the laws of evaporation from large water surfaces; and the line of investigation is to treat each one of the Great Lakes as an evaporation pan. Therefore the study is directly connected with the Great Lakes; that being the line of attack which was outlined in my application for the grant and the line of application which is being followed.

Q. Have you done any work on the Alaska and Canadian boundary lines?

A. Yes. In connection with the surveys for the Coast and Geodetic Survey, the Superintendent of the Coast and Geodetic Survey being a commissioner in connection with those surveys, my control of the triangulation brought me in touch with those boundaries and therefore I had full knowledge in regard to that and was responsible for certain parts of the work on the Alaska boundary surveys and the surveys of the boundary between the United States and Canada.

Also I was on the Alaska Boundary Survey before the arbitration, one summer season, in the Coast and Geodetic Survey.

Q. Just a little more in detail, what does that boundary work involve; as far as you were concerned, what did you have to do?

A. In the Alaska and Canadian Boundaries, you refer to?

Q. Yes, any of the boundary work, what is your work?

A. Well, to go back to the Mexican boundary, the two years there, I did all of the astronomical work on that boundary from El Paso to San Diego; that is the determinations of the latitudes and azimuths, true directions; running out also 230 miles of the boundary on the ground, running it out for the United States.

On the Alaska boundary, the one summer season I was up there simply on the astronomical work; but later in connection with the Alaskan boundary and the Canadian boundary, I was in charge of certain parts of the triangulation and in charge of certain parts of the computations in connection with the triangulation. It was the computation largely in those later years that I had charge of, in connection with that work.

Q. All of this work involved the taking of observations and making computations and reductions from them?

A. Yes. It has been so in all parts of my service in the coast survey and on these other surveys each has involved computations continuously; that is involved having charge of the computations; not directly in the making of them individually, of course.

Q. Will you state under whose direction or by what institution this investigation of evaporation is being made?

A. Made under the Carnegie Institution at Washington.

Q. Why was that undertaken?

A. I believed that our knowledge of the evaporation from

large water surfaces, the knowledge which is now in the hands of the engineering profession, was very weak and inaccurate; and I believed that there was a line of attack by way of the Great Lakes which would improve that knowledge. I so stated to the Carnegie Institution, and the grant was made because I convinced them that I was probably right in that view.

Q. What are the present methods in regard to evaporation on the Great Lakes, and why are they likely to be inaccurate?

Mr. Austrian: Do you mean his methods?

Mr. Hopkins: No.

Mr. Austrian: Methods other than yours?

The Witness: Yes, practically all of our knowledge, the knowledge of engineers of evaporation at the present time is derived from observing evaporation from small pans with a water surface of a few square inches, or at most a few square feet; and what is really desired, what is really needed is the evaporation from large water surfaces such as a water reservoir or a lake.

Now it is my belief that the change in condition from that at the pan where the observations are made to an open lake is such an extreme change that when one reasons from the pan to determine what occurs in the lake, that reasoning is very defective; that the difference in conditions is so great that the conclusion as to the evaporation from the reservoir or a lake is a very weak conclusion. The conclusion may be in error in the tens of percentage.

Q. Have you come to any conclusion yet?

A. On the evaporation? No, sir, the investigation has not progressed far enough.

Mr. Austrian: How long have you been at it?

A. It is about two years, but it has been done in fragments of time, when nothing else was on hand to do. And according to my estimate for the Carnegie Institution I should be much less than half done at the present time.

Q. That is you figured it would take about five years?

A. I told them it would take from three to ten years.

Q. From three to ten?

A. Yes, that was the original estimate of the time it would take me.

Q. You are much less than half through. You have kept your promise, I take it?

A. Yes, sir.

Mr. Hopkins: Q. Mr. Hayford, you have made certain

studies of the measurements made by the Lake Survey of the Niagara River, have you not?

A. Yes, sir.

Q. What has been the source of your information, and what have you studied, just tell us?

A. First the document known as the Preservation of Niagara Falls.

Q. Do you have the date of that?

Mr. Adcock: That is the same thing we have heard about before.

Mr. Austrian: That is the one prepared by Professor Shenehon I take it?

Mr. Hopkins: Prepared by Mr. Shenehon.

The Witness: Yes, sir. Second the portions of the Lake Survey Reports, 1900 to 1902, which deal with the discharge of the Niagara at the Niagara gagings there.

Mr. Austrian: Q. Those are in evidence, I take it?

The Witness: Then three blue prints which I have here, three sheets showing the measurements of discharge at the International Bridge Section.

Mr. Hopkins: Which are in evidence in connection with Mr. Shenehon's testimony as to the observations taken at the International Bridge Section and the Open Section. I am stating that. You can check it up, Mr. Williams.

Mr. Adcock: Let us see if we cannot refer to that a little more specifically.

Mr. Hopkins: I have not the exhibit numbers.

Mr. Austrian: Don't they show on the face, the exhibit numbers?

Mr. Adcock: It is Williams' Exhibit 24. When you refer to those, they are Williams' Exhibit 24.

The Witness: There are three sheets for the International Bridge Section and two sheets for the Open Section. They are all in one exhibit.

Mr. Adcock: They are all Williams' Exhibit 24.

The Witness: Next, five sheets of a computations made on the Williams' Three Point Method; a computation which I understand was made by Mr. Shenehon.

Mr. Hopkins: Is that in evidence, Mr. Shenehon?

Mr. Shenehon: That was referred to in the cross-examination of Mr. Williams, and pronounced correct by Mr. Williams.

Mr. Williams: Five sheets, you say?

Mr. Adcock: Just a minute—

Mr. Williams: I have no recollection about it from this—

Mr. Adcock: We will not admit that those were introduced or offered in evidence or identified.

Q A part of the things you considered then were five sheets which I now hand you, which we will ask to have marked Hayford's Exhibits 1, 2, 3, 4, and 5 of this date, April 10. Those are offered for identification.

(The five sheets above referred to were here marked for identification Hayford's Exhibits 1, 2, 3, 4 and 5, April 10, 1914.)

A. Next is four blue prints, each showing three curves of elevation at Buffalo; the discharge of the Niagara River and the elevation at Suspension Bridge.

Mr. Shenehon: That is the three sheets, what has been called the Three Curve Series.

The Witness: Four sheets.

Mr. Shenehon: Four sheets.

Mr. Hopkins: Identified on Williams' cross-examination as Exhibits F, G, H and I, Government's Exhibits.

Mr. Williams: October 9, 1913.

Mr. Hopkins: Q. What else, Mr. Hayford?

A. And three blue prints one curve each, showing a discharge of the Niagara River.

Mr. Shenehon: Those are Exhibits J. K and L, of the same date?

Mr. Hopkins: That is subject to correction.

Mr Adcock: By us, after examination.

Mr. Hopkins: As to whether or not it is a correct copy.

Mr. Williams: I have a copy of the blue print. I haven't a copy of this.

Mr. Hopkins: Q. What else, Mr. Hayford?

A. One blue print showing the discharge of the Niagara River and the elevations at Suspension Bridge and Whirlpool.

Mr. Hopkins: What is that exhibit?

Mr. Shenehon: That has never been put in.

Mr. Hopkins: I would like to have that marked Hayford's Exhibit 6, of this date.

Mr. Adcock: For identification?

Mr. Hopkins: For identification.

(Blue print referred to by witness was marked Hayford's Exhibit 6, April 10, 1914.)

Mr. Hopkins: Q. Anything else?

A. One blue print of the discharge curve for the Open Section.

Mr. Shenehon: That has never been put in the testimony and may be identified.

The Witness: It is the blue print from this tracing (indicating).

Mr. Hopkins: We have the tracing, and I would like to have it marked as Hayford's Exhibit 7, of this date, for identification.

(Tracing referred to by witness was marked Hayford's Exhibit 7, April 10, 1914.)

The Witness: Finally a similar one for the Bridge Section.

Mr. Hopkins: Which is here referred to and marked for identification Hayford's Exhibit of this date.

(Document identified by witness was marked Hayford's Exhibit 8, April 10, 1914.)

Mr. Hopkins: Hayford's Exhibit 8 is a reproduction of the curve shown on Haskell's Exhibit 1, of February 3d, 1914.

Q. Just in a general way, Mr. Hayford, what are these things you have studied; first the five sheets, the blue prints?

Mr. Adcock: I object to that on the ground it is impossible for him to answer it.

Mr. Austrian: What do they purport to be? Unless they are an accurate reproduction, they are nothing.

A. They show the measured discharge of the Niagara River, 340 measurements other than a few made under ice conditions, but 340 that were used; and they also show the corresponding stages of the lake at Buffalo, and some other information connected with the observations, wind velocities, etc.

Mr. Austrian: Q. You had nothing to do with the making of the observations or the plotting of them, did you?

A. I did not.

Mr. Hopkins: Q. What do the other documents that you have referred to show in connection with those measurements—or purport to show, Mr. Hayford?

A. The Three Curve and One Curve blue prints show the portions of the same information in other forms, in graphical form. The two discharge curves show the observations again in another form, and also show lines based upon those observations, conclusions drawn by some other person, conclusions drawn from the observations; and the remaining blue prints, of course, have other information in regard to the elevation of the water surface at Suspension Bridge and Whirlpool with a little information with regard to elevation at Cleveland of the water surface.

Mr. Austrian: Q. You had nothing to do with making those observations or plotting them upon these various maps?

A. I did not.

Mr. Hopkins: Mr. Hayford, from the study of those things that you have just referred to, can you tell whether or not the observations shown there were accurately made?

Mr. Adcock: Just a minute; I object to that question on the ground that the witness has not shown that he is qualified to answer that question.

Mr. Hopkins: Go ahead.

Mr. Austrian: Do you mean accurately made upon the maps or plats?

Mr. Hopkins: No, the observations taken, the man who was the observer.

A. I believe the degree of accuracy of the observations and of the results can be and has been determined from the data.

Q. Well, in this case, what is your opinion as to the accuracy of the observations?

Mr. Austrian: That is all of them, all of the exhibits that you have referred to?

Mr. Adcock: I object to that on the further ground that it is impossible for him to tell from those papers that are presented whether the measurements were taken accurately or that the observations are accurate.

Mr. Austrian: Your question is not quite specific.

Mr. Hopkins: My question was, from what he has studied, whether or not he can tell that the observations which are plotted there—

Mr. Austrian: On all the exhibits that he has referred to.

Mr. Hopkins: Yes.

Mr. Austrian: That is five or six, or eight or ten of them?

Mr. Hopkins: Whether they were accurately observed; and if not wherein there is any variation.

Q. Go ahead and explain in your own way whether from that data alone you can tell, form an opinion as to the work of the engineers in the field.

Mr. Adcock: You mean without regard to his knowledge as to whether the observations were taken accurately or whether he knows anything about the conditions existing at the time, or anything like that?

Mr. Hopkins: He will give us his reasons.

A. From the data, and from the printed documents, from the general literature of the subject; from the examinations I

have made, in the manner I would like to state fully later, the degree of accuracy of the observations, and the conclusions from them have been determined. I have made such an estimate of the accuracy which I believe to be reliable within certain limits.

Mr. Adcock: I move to strike out that answer on the ground he has taken into consideration other things than the papers and documents which have been presented to him.

Mr. Austrian: And other things than the documents in evidence.

Mr. Hopkins: Q. In addition to the things you enumerated awhile ago, that you have studied, is there anything else that you took into consideration, Mr. Hayford, in that matter; and if so, what?

A. In getting the sidelights on the whole matter, why, of course, I read other articles like Hoyt & Grover's book on stream measurements, dealing with the general matter of current meters; a recent article by Grote in the American Society of Civil Engineers, treating of current meters again.

Q. Which is in the record in this case? That is the article by Grote, referred to by Mr. Freeman.

A. (No response.)

Q. Go ahead, Mr. Hayford, what else did you identify?

A. And other published reports by the Lake Survey, in connection with other stream gagings, to determine the general methods used and the results obtained in other cases; that is for general information as to the methods and their reliability.

Mr. Adcock: Q. What stream gagings do you refer to, made by the Lake Survey?

A. To the St. Lawrence and the St. Clair River, St. Marys River and those—

Q. Niagara River?

A. Niagara River; of course that is all included.

Q. Including the Detroit River?

A. Some measurements in the Detroit River and some experiments on current meters at Detroit.

Q. Do they appear in the reports of the Chief of Engineers, United States Army?

A. Yes, sir.

Q. Only?

A. No, other articles in regard to these same matters in other places, as I utilized all of the engineering literature I could get time for to be well posted in this matter.

Q. I am referring particularly to the Lake Survey report. Did you refer to any other reports of the Lake Survey than the ones which appear in the Chief of Engineer's Report, United States Army, with reference to the stream gaging of the rivers which you have mentioned?

A. It is the Lake Survey, yes, in the Chief of Engineer's reports.

Q. That only?

A. Only for the Lake Survey work, yes, but I referred—this document on the preservation of Niagara Falls is already referred to, of course. It involves work done under the direction of the Lake Survey.

Q. That report on the Preservation of Niagara Falls was made by Mr. Shenehon?

A. Yes.

Q. Of the Lake Survey?

A. Of course the earlier gaging at Niagara Falls, at Niagara River rather, done by Mr. Clinton B. Stewart, was published in the transactions of the Western Society of Engineers. I looked that up also.

Mr. Hopkins: Mr. Hayford, these other things you have referred to are matters of general literature on river measurements that you have used to qualify yourself?

A. Yes, sir, on river gagings, and on the use and the performance of the current meters, especially the Haskell current meter.

Mr. Adcock: Is that the A or B meter?

A. Both, and quite a number of meters; not simply two. Of course there had been many Haskell current meters used in various parts of the work.

Q. By the Lake Survey?

A. By the Lake Survey; by other organizations. I am familiar also with the use of that meter in the Coast and Geodetic Survey. It has been used in the Coast and Geodetic Survey for many years.

Mr. Hopkins: Q. Now from all of that information that you have mentioned, do you have an opinion as to the accuracy with which the observations were actually made?

A. I do.

Q. State your opinion and the reason for it.

Mr. Austrian: That is the observations indicated upon the various maps and plats and tables you have just introduced in evidence for identification. Is that correct?

Mr. Hopkins: All that he has referred to.

Mr. Austrian: Yes, that he has referred to here in evidence. He has referred to a lot—

Mr. Adcock: I want a further objection there.

Mr. Hopkins: That he has referred to, which are in evidence, or which we identified, marked for identification today. I refer to these blue prints in evidence and William's Exhibit 24, five blue prints.

Mr. Adcock: I make the further objection he has not shown that he is qualified to answer that question.

Mr. Hopkins: All right, go ahead; what is your opinion as to the accuracy, Mr. Hayford, and why?

A. It is my opinion that those observations—I think I can state the accuracy best by stating the conclusion drawn from them, from my investigation of the accuracy of the conclusions, and then come back to the individual observations.

I believe those observations establish that the discharge of the Niagara River, when the elevation of the lake surface at Buffalo is 572 feet even, is 195,740 cubic feet per second; and as to the accuracy of that conclusion, that it is an even chance that this value is within one half per cent. of the truth, and it is practically certain that it is within 2½ per cent. of the truth.

Then the observations also establish that the increment of discharge corresponding to one foot of increase in the elevation of the water surface at Buffalo, is 21,860 cubic feet per second. Now, as to the accuracy of that increment, it is an even chance that said value is within 1 per cent. of the truth, and it is practically certain that it is within 5 per cent. of the truth.

Now, as to the individual measurements of the discharge, the greatest error occurring in any one of the 340 measurements already referred to is 4¾ per cent. That is about 9,000 cubic feet per second. Now, all other observations of the 340 observations have smaller errors than that.

As to the general line followed in reaching those conclusions: First, taking the 340 observations—the one qualifying statement that I ought to enter in there in regard to the discharge at the 572-foot level is, of course, that refers to the discharge under the average actual conditions in the Niagara River, when there is no ice in the river. Now, then, as to the line of attack in reaching these conclusions: First, I took the 340 observations. They stand in two groups; one in the Bridge Section, one in the Open Section. For the Bridge Section, I took approximately the first half of the ob-

servations, those made from July 16, 1898, to May 19, 1899, and made a complete and very thorough computation by the least squares method of the mean discharge and the increment of discharge from those.

I took them the latter half of those observations; that is, 118 observations made between October 21, 1907, and August 6, 1908, the dates inclusive, of course, made a similar computation from those. Then, taking the measurements on the Open Section, I divided those into two groups approximately equal. These groups are in their order of time; they are simply chronological groups; took the first 58 observations from August 30 to October 31, 1899; made a complete computation on that group. Next I took the group of 63 observations on the Open Section from November 1st, 1899, to July 24, 1900, and made a complete computation on those. That made four computations.

Then I took the whole 219 observations on the Bridge Section, as a single group; made a complete computation with those. Similarly, I took the 121 observations on the Open Section and made a complete computation. That made six computations each on a part of the observations.

And, finally, I combined the last two computations named and derived from the whole group, these 340 observations, what I believe to be the best values now determinable from these observations on the discharge and the increment of discharge for the Niagara River.

Now, then, from those computations, by comparison of the six computations with each other and a comparison of each one with the final computations which included them all, I could get some evidence as to the reliability of the results.

I also went over carefully all of the internal evidence afforded by those computations, the internal evidence being that given by the disagreement of the observations from each other; and also in studying that internal evidence, I studied very carefully the relation between each of the observations and such of the surrounding conditions as I could find recorded in these various sources of information. And next I took the certain other computations which had been made, using this same data, or parts of it, and compared the results with those other computations with the computations I had made. The other computations were, first, this determination of the discharge and the increment made by stretching a thread, as I understand it, over a plotted sheet—

Mr. Adcock: A string?

The Witness: I am not certain whether it was a thread or a string.

Mr. Adcock: It might be either one.

The Witness: It might be either one. It was a straight line, portable straight line, stretching it over a plot. There was such a determination shown on one of these blue prints before me; a determination based on the 219 observations at the Bridge Section. A second one made in the same way on the 121 observations at the Open Section.

Q. Was that with a string, too?

A. With a string also. Then I found in the Lake Survey Report, 1912, Appendix FFF, on page 3547, a statement of the discharge of the Niagara River in terms of the elevation of the lake surface at Buffalo. That is the result of a similar computation. The details of that computation I don't know, but I took out the result from the publication, for comparison with these other results.

I compared also with those computations two results shown in Appendix III of the Chief of Engineers, report for 1900, page 5361, two computations made by Mr. Shenehon, or under his direction; one from 86 observations at this Bridge Section, being a part of the observations of the 219; and also a computation made under his direction from 63 of the observations on the Open Section. That is on the Bridge Section, they were observations from September 10 to December 10, of 1908, the earlier part of the series. In the case of the Open Section, they were observations from October 4, 1899, to June 30, 1900; again the earlier part of the observations.

I also compared with the computation made from observations of the discharge at the International Bridge by Clinton B. Stewart and published in the Western Society of Engineers' transactions. And, lastly, I compared with the computations on the five sheets introduced in evidence on the Williams Three Point Method.

Mr. Hopkins: That is Hayford's Exhibit 1, 2, 3, 4 and 5 of this date?

A. Yes, that is a computation made by the Three Point Method, using the 219 observations at the Bridge Section.

Now, those were then seven different computations based on various sets of observations; all computations giving the discharge of the Niagara River in terms of or as related to the water level at Buffalo. Those different computations, in comparison with the comparisons I have made, served also

to indicate the accuracy, the degree of reliability of the various conclusions; served as checks.

Mr. Adcock: Q. Was this on the internal evidence?

A. These other computations are in part external evidence, inasmuch as they included in some cases other observations and also inasmuch as they were computations made by other methods.

And finally, after that line of attack, then I undertook to study the methods of observation and the computations very carefully to determine, if possible, or as far as possible, the source of the various unavoidable errors in this work, and in all such work traced back the errors to their source, so as to be able to determine what effect various conditions had on the accuracy and reliability of the final result. That was a study in detail of the different sources of error. I have a list of those sources of error and the—

Q. Go right ahead and state them.

A. The accuracy or size of the errors which could be traced back to those causes.

Q. What are those possible errors and what effect do you think they would have?

A. First, as to the effect they might have on the computed discharge, and then I would like to state later the effect each of these sources of error might have on the completed increment. The two effects will be different, expressed as percentages.

First, as to the effect of those different errors on the computed discharge at a mean elevation of say, at the elevation of the lake surface, 572 feet, which is practically the mean elevation. First, as to the measurement of the area of the cross section of the stream at the point where the gaging, stream measurements were made, I estimate that the maximum error in this final divided result due to that cause is 1 per cent.; that is the maximum. It is the maximum in each case I propose to state.

Mr. Adcock: That is the discharge?

A. No, cross section. That is the error in the discharge due to errors made in determning the cross section. Of course, it includes errors of sounding, which is a part of the work of getting the cross section.

Now, the errors in the mean discharge, coming from the ratings of the meters, that is the current meter, the meters

used, the maximum in that case is 1 per cent., maximum possible error in the final derived value of the mean discharge.

Q. Did you consider that they used a Haskell meter in that connection?

A. Yes.

Q. A or B meter?

A. Both, several meters. That is, I traced up, studied the details as to what meters they used and how they were rated. In the determination of the velocity ratios, the errors due to errors in the determination of velocity ratios is a maximum of ¼ of 1 per cent. in that mean discharge.

Mr. Williams: Just what do you mean by velocity observations?

The Witness: In the determination of the ratio of the velocity at various points in the cross section and the velocity at the index station.

Next, the maximum error in the mean discharge, which may arise from the effects of turbulence in the stream, including the pulsations, is 1/10th of 1 per cent.

Next, the maximum error in the mean discharge which could arise from the effects of winds, is ¼ of 1 per cent. Remember, this is the mean discharge under the average actual conditions.

Mr. Adcock: Q. Of the 340 measurements, that is all the measurements?

A. Yes, the error in the mean discharge under actual conditions due to the accumulation and the removal of weeds, removal by the current by natural causes, I mean, I find to be negligible so far as the mean discharge is concerned. Also so far as the mean discharge is concerned, the errors due to lag effects and to backwater effects, I find to be negligible. When I say negligible I mean it is well under 1/10th of 1 per cent. And finally—

Mr. Adcock: Q. You did not compute the error closer than 1/10th of 1 per cent.?

A. Yes, that is when I satisfied myself that the error was well under 1/10th of 1 per cent., I called it negligible.

Now, the maximum error in the mean discharge, which could arise from errors in the determination of the direction of flow at the current meter was 1/5th of 1 per cent.

And, finally, I studied the matter to ascertain whether there was a possible error in this computed mean discharge due to

any possible difference in the discharge on disturbed days as contrasted with quiet days; meaning by disturbed days either the days when there was a high wind velocity at or near Buffalo, or days on which the water surface at Buffalo was rapidly fluctuating. And I found that there is no relation discoverable between disturbed days in either of those senses and the discharge itself. When I say no relation between disturbed days and the discharge, I mean between discharge on a disturbed day that is found in that way, or the day after. That is, it is conceivable possibly that if you had a disturbed day it might disturb the flow for some hours thereafter. Therefore, I examined the matter not only to see whether the day itself on which the observation was made was disturbed, in the sense defined, but also examined the record for the preceding day.

Mr. Hopkins: Q. Is that all, Mr. Hayford?

Mr. Adcock: Q. There is nothing there, it is neglible.

A. No relation between the discharge and the disturbed days.

Q. There is no error?

A. No error due to that cause.

Q. You marked that, "winds negligible"?

A. Yes, you might put it so.

Mr. Hopkins: Q. You mean, Mr. Hayford, that there is a direct connection between the stage at Buffalo and the discharge, regardless of whether or not the lake is quiescent or fluctuating?

A. Yes. That is, it is the mean level at Buffalo, there is a direct connection between the mean level at Buffalo during the time when the discharge observations were made and the discharge itself.

Q. And in getting that result you took into consideration a series of observations?

A. I took into account all of these 340 observations and the evidence as to the lake surface at Buffalo. The lake surface, of course, was shown by continuous curve of lake levels shown on these blue prints which have been introduced here in evidence.

Q. Mr. Hayford, what is your final conclusion, then, as to the maximum error in the volume of flow?

A. You mean the maximum error in any single observation, or the maximum possible error in the final deduced result?

Q. Of the 340?

A. Well, my conclusion is that from the 340 observations studied fully the discharge of the Niagara River corresponding to 572 feet even for the lake level at Buffalo is 195,740 cubic feet per second; and that it is an even chance that that value just stated is within ½ per cent. of the truth, and it is practically certain that within 2½ per cent. that is so far as the discharge is concerned at that elevation, which is practically the mean elevation.

Q. What would you say as to the probability of it being the maximum, the 2½ per cent.?

A. It is practically certain that the error is less than that maximum.

Q. The probable error is ½ of 1 per cent.?

A. Yes, ½ of 1 per cent.; that is, it is an even chance that the value stated is right within ½ of 1 per cent.

Q. Did you compute an increment of discharge for a foot difference in the level?

A. Yes. That computation, or that determination, is a part of the same computation.

Q. What increment did you derive?

A. I found the increment corresponding to 1 foot increase of elevation in the lake surface at Buffalo was 21,860 cubic feet per second; and as to the accuracy of that conclusion, that it is an even chance that that value is within 1 per cent. of the truth. It is practically certain that it is within 5 per cent.

In regard to that value of the increment, I may say that I studied these separate sources of error in the same way, as to their effect upon increment that I have already outlined in connection with the mean discharge, so if you care for it I could give you the possible errors in the increment due to these various sources.

Q. Go ahead, Mr. Hayford.

A. Now, as to the possible maximum, possible errors which may arise from these various sources in the computed increment from the measurement of the cross section including the soundings, the maximum possible error in the increment so produced might be 1 per cent. The maximum possible error in the increment due to errors in the rating of the meters, ½ of 1 per cent. I am following the same order in the statement that I did before, for the different items.

The maximum error in the increment which could arise

from errors in the determination of the velocity ratios, ¼ of 1 per cent., from the determination of velocity ratios. The maximum error in the increment which could arise from the effects of turbulence, including pulsations, 1/10th of 1 per cent.

Mr. Adcock: Q. That is the same as the other?

A. Yes, on certain items, for instance on that particular item they are the same, but not all the way through. The maximum error in the increment which may possibly have arisen from the effects of winds, ½ of 1 per cent.

Q. That is more, isn't it?

A. Expressed as a percentage, yes. The maximum error in the increment which might arise from the changing of the condition as to weeds, 3 per cent.

Q. That was negligible before?

A. Yes. The errors from lag, back water and from the determination of the direction of flow at the meter, neglible.

Q. That was ½ of 1 per cent. and negligible as to lag and back water in the other, wasn't it?

A. (No response.)

Q. There is another one, disturbed days.

A. Now, the effect of the disturbed days defined as already stated, I find that there could be no error, no appreciable error in the increment from that cause.

Q. That is negligible, too?

A. Negligible, yes. Now, each of these estimates are estimates of—

Q. Did you get the ratings and cross section as to increment?

A. Yes, those were stated.

Q. What were they as to increment?

A. As to increment, measurement of cross section 1 per cent.

Q. 1 per cent.?

A. And the rating of the meters ½ of 1 per cent.

Mr. Hopkins: Go right ahead.

A. Each of these estimates are estimates of the maximum which could come from the causes. Of course as these errors are not necessary, in fact it is pretty certain they cannot all be of the same sign and that you could not have a maximum possibly occurring on all of them, the total error would not be obtained by adding up those quantities. The total error is —I have already estimated as 5 per cent.

Mr. Adcock: Five per cent.?

A. As the maximum possible in that increment; that is, it is practically certain that the stated value of the increment is correct within 5 per cent.

Mr. Hopkins: Q. What are the probable errors?

A. For the increment?

Q. Yes?

A. One per cent. That is, it is an even chance that the increment is right within 1 per cent.

Mr. Adcock: Q. That is, you changed the signs on some of them?

A. The errors from these separate sources, some of them may be of one sign, some of another. Moreover, in all of those you will not have a maximum possible error occurring on all of them. Some of them will be less than the maximum.

Mr. Williams: Not at the same time.

A. Not at the same time, and these are estimates of the effect on final result.

Mr. Adcock: That must be a difficult matter to get it, isn't it, then, to determine the signs for each one, and to determine the 1 per cent. probable error?

A. Certainly it is a difficult matter.

Q. Mr. Hayford, what effect would the diversion of 10,000 cubic feet per second at Chicago have upon the level of Lake Erie?

Mr. Adcock: You are only stating that from these things—

Mr. Hopkins: From the conclusions you have reached.

Mr. Adcock: And the papers you have before you?

A. Yes, from these observations. That the loss of level of Lake Erie, corresponding to a loss of outflow of 10,000 cubic feet per second, is 5½ inches. That comes from converting the increment into a loss of level.

Mr. Hopkins: Q. Mr. Hayford, now from that data that you have, and that you testify you have used, from the observations that are set out before you, assuming that they are correctly copied and handed to you in those documents you have referred to, can you tell whether or not the observer did his work carefully and accurately?

A. I can.

Q. How?

A. From the lines of evidence and the lines of examination that I have outlined. From the internal evidence of the computation; from the comparison of different computations with each other, and from the study of the details of the methods.

Q. Suppose they were careless in their observations, how would it appear in the results which you have before you?

A. It would appear by there being larger disagreements between the observations than I actually find. It would appear by there being large discrepancies between the different computations when they were based on parts of the observations in turn, as I have indicated in the six different computations.

Q. And in that number of observations, 340, what would be the tendency of any error of observation?

A. That is as the number of observations increased, or is increased, of course there is afforded a greater opportunity for the errors of observations and errors due to varying conditions to cancel themselves out, to eliminate each other, so that in a large number of observations the error in the final result based on all of them will be, of course, smaller than the error of any one result or in the average result.

Q. Mr. Hayford, your main study was from these tabulations found in Williams' Exhibit 24, was it not?

A. Yes, the five blue prints.

Q. And the charts or maps you referred to, and the plats were used to check with it, were they?

A. Exactly. The figures used in the computation were taken from these tables.

Q. You assumed that those charts were correctly plotted, did you?

A. Yes, and also checked them up in parts by comparison with these tables as the originals. In certain parts I did check them, so that I didn't have to take the plots entirely on faith.

Q. Have you given us all of the study or reading that you have done to qualify yourself upon the question of reduction of observations of river measurements? In other words, did you study hydraulic engineering in college?

A. I did. I think I may answer that question in this way: I have given you all of the reading which I did for this specific purpose; but in college, of course, as a part of a civil engineer's training, I necessarily read and studied along this line, and also in connection with the Coast Survey work, with this evaporation investigation. Also long before I was called on in connection with this case, I had read along these same lines at various times. I have not given you those readings, of course.

Mr. Adcock: Q. That was all your hydraulic experience?

A. I don't understand your experience.

Q. Was that all of your hydraulic experience?

A. I think I have indicated in a general way all of it.

Q. That was in college?

A. (No response.)

Mr. Hopkins: Q. Would you consider, Mr. Hayford, that your experience in reduction of engineering observations through all of that period qualified you to reduce the observations of an hydraulic engineer, just the same?

Mr. Austrian: Objected to on the ground you cannot prove that the witness is qualified as an expert by asking him whether or not he is an expert.

Mr. Hopkins: Read the question.

(Question read.)

A. I do. I have been practically continuously since I graduated, since 1889, working on computations and in general charge of them.

Mr. Adcock: I move that answer be stricken out as not responsive to the question.

Mr. Hopkins: Q. Will you now state just what work you have done in connection with the reduction of observations, what qualification you have had, and how that is applicable to the work which you have just done in connection with this matter?

Mr. Austrian: The first part of that I think he has answered already.

Mr. Hopkins: Maybe he has, but let us repeat.

A. In all of the work which I have already outlined in the Coast and Geodetic Survey, and in connection with other surveys, especially in the Coast and Geodetic Survey, while in charge of their computing along certain lines, I was dealing with the general problem always of deriving the correct and reliable conclusions from field observations. That problem is the universal problem. That is the same problem everywhere, regardless of what kind of observations you are dealing with. At least there are many features of the problem that are the same. It is that general training which I believe qualifies me to derive the correct conclusions from field observations and to determine the reliability of the conclusion, degree of reliability, degree of accuracy after it is derived.

Mr. Adcock: I move to strike out all after the words "it is that general," etc., on the ground it is within the province

of the court to determine whether he is qualified, and not for the witness to determine.

Mr. Hopkins: Q. In other words, it is purely a mathematical question, isn't it, Mr. Hayford?

A. The determination of the relation between the discharge of the Niagara and the lake level at Buffalo is in part a purely mathematical question, a method of computation. It is in part, of course, an engineering question, a study of the data and the methods.

Q. What is your opinion as to the applicability of the method of least squares?

A. To this problem?

Q. Yes?

A. It is my opinion that that is the best method of computation to be used to get the most reliable conclusions out of these measurements or any other extensive set of measurements.

Q. Now how about the three point method?

A. The three point method, as shown in the computation which has been put in evidence, I have compared with the least square method. It is my opinion that the three point method as so applied in this case ignores or excludes about ⅓ of the evidence given by the 340 observations.

(Answer of witness read.)

The Witness: I should correct that: The three point method, as applied here, was to 219 observations, not 340.

Q. As a general proposition the three point method would bring about that result?

A. Yes, the three point method, as applied to any case, will exclude a considerable portion of the evidence given by the observations. It may be more or less than ⅓, but it will always exclude a considerable portion of the evidence.

Q. Do you regard it as a correct mathematical method to use in the reduction of observations?

A. Well, it will give an approximation to a correct result. The method is incorrect only, or mainly, in that sense that it utilizes a part only of the evidence given by the observations. If you chose I can indicate further how it excludes a part of the evidence.

Q. Yes, go ahead.

A. As applied to this particular case, for example, the three point method was applied by first deriving the mean elevation of the lake at Buffalo corresponding to the 219 observa-

tions. That mean elevation was 572.549 feet. Now, then, all of the observations which were made when the lake at Buffalo was above that elevation were placed in one group, which I will call group 1 for convenience, and all of the observations made when the elevation at Buffalo was less than that value were placed in another group, which I will call group 2. Then the mean elevation and the mean discharge were computed separately for each of those two groups. That gave two mean elevations and two mean discharges. And finally, the increment was derived by dividing the difference of the two discharges by the difference of those two elevations, the mean discharges and mean elevations.

Now, such a method of computation ignores evidence in this way: If you take the second group, it includes the third observation made on October 24, 1907. And it also includes the first observation made on November 10, 1898. They both fell in group 2. Now, the lake elevation corresponding to the first of these observations was 572.54, and the second observation was 570 even, differing by 2.54 feet; the lake level being lower during the second observation.

Now the measured discharges were for those two observations, for the first one 209,230 cubic feet per second and for the second observation 154,100 cubic feet per second. Those two differ by 55,000 cubic feet per second, the second one being the smallest.

Now, these two differences, the difference in elevation of the lake at Buffalo in the two cases and the difference in the two discharges, are entirely included in the three point method, because you have simply included both those observations in getting the mean for the second result group, and the result of that mean is identical with what it would have been if you have the large discharge, 209,230 cubic feet per second, with the small elevation, 570 feet, and vice versa if you had the small discharge with the larger elevation.

In other words, if you interchanged the discharges and let the elevations stand, your computation, the final result of the computation from the three point method, will be unchanged. Therefore, that method of computation ignores the evidence that when the lake surface dropped 2.54 feet that that discharge diminished by 55,000 cubic feet per second.

Every one of such differences that are within the second group are ignored as a part of the evidence. And similarly any pair of differences like that that is in the first group is

ignored. Evidence of that kind, the internal evidence of each group by itself, is entirely ignored in the three point method; and as applied to this case, that is about $\frac{1}{3}$ of all the evidence, is ignored, so that the fact that the three point method gave a result nearer the result from the least squares method of computation merely goes to show that the errors of observations and the errors due to the variations in conditions are small.

Of course, if the evidence in any case is all accordant, or closely accordant, then you can reject a part of it and get nearly the same conclusion that you would if you took in all the evidence; and that is the nature of the reason why the three point method, as here applied, gives nearly the correct result.

Q. Now, how about using a thread, Mr. Hayford?

A. The method of stretching a thread over the plot of the values, that method takes into account all of the evidence shown on the plot; that is, if the plot is made with the individual observations, then it will take in the evidence and all of it from all of the observations; it takes it into account, however, with some inaccuracy on account of the fact that the man is using his judgment, his eye simply, and not making a careful computation; and, of course, it involves the judgment of the individual man stretching the thread. But it does take all of the evidence into account.

Q. It depends somewhat, then, upon the skilfulness of the man who did the work?

A. The skilfulness of the men and the judgment used in selecting the scale, both scales, vertical and horizontal, of the plot.

Q. In this particular case, Mr. Hayford, an increment derived by a thread showed 21,900 cubic foot. What would be your opinion as to whether or not that method of using a thread was approximately correct?

A. It would necessarily, as applied to this case and with these particular plots give a close approximation to the correct result. All of the valuations, values, are, which were secured from two applications of the thread method.

Q. Without going into any great detail, are they almost identical?

A. Yes, very nearly identical with my derived value; one on one side, one on the other.

Mr. Adcock: Q. I suppose the judgment of the observer was used there in getting the result, is that so, is that true?

A. I take it he had to use his judgment to get a result.

Q. He could get about what he wanted to?

A. I didn't make that statement.

Mr. Hopkins: Q. Mr. Hayford, you did not take into consideration, in the results that you have given, any measurements made at what we have called a third section down near Grand Island?

A. No, I did not.

Mr. Adcock: The Split Section.

The Witness: I did not take that into account. I had no information in regard to that further than that there had been some measurements made, but I had none of the records of those measurements.

Mr. Hopkins: Q. Suppose, Mr. Hayford, that ten observations were made at another point in the river, that is known in this case as the Split Section, under the same general conditions as to care of the observer as appears in the other sections, the results of which you have before you, and in regard to which you have testified, by an engineer in the Lake Survey Office, and the results obtained by him checked within 1 per cent., a little over 1 per cent. of the results at the Open Section and the International Bridge Section, which you have examined, falling between the two. What effect, if any, would that have upon your opinion as to the accuracy of the volume of flow which you have already testified to?

Mr. Adcock: I object to that on the ground it assumes a condition which does not appear in the record in this case.

Mr. Hopkins: Specify, Mr. Adcock.

Mr. Adcock: I do not need to specify.

Mr. Austrian: Condition or state of facts.

Mr. Adcock: Condition or state of facts not in evidence, and not appearing in the case.

Mr. Hopkins: Q. Do you understand the question? Will you answer it, please?

A. That would simply, to my mind, confirm the reliability of the conclusions I have drawn as to the accuracy of the mean discharge as computed from the Bridge and Open Sections; from the measurements in the Bridge and Open Sections; that is, a close agreement of that kind would confirm conclusions I have already stated.

Mr. Adcock: Q. Then, would you reduce the error, percentage of error, that you formerly computed?

A. No, on simply that evidence I would make no change in these estimates.

Q. I take it you state your conclusions there as to the percentage of error with a great deal more assurance, is that the idea, after the hearing of these other measurements?

A. Yes, when I have additional evidence which confirms evidence already in, I feel my conclusions to be still safer than before.

Q. But you would not reduce the percentage?

A. No, I would not; not simply on that amount of additional evidence. It was too little to change the conlcusion.

Cross-examination reserved.

Adjourned subject to notice.

JOHN F. HAYFORD was recalled as a witness on behalf of the Government and testified further as follows:

Cross-Examination by Mr. Adcock.

Q. Have you ever made any so-called current meter gagings or measurements of discharge of rivers, with a current meter?

A. I have not.

Q. Have you ever been present when such gagings were made?

A. I have not.

Q. Did you ever use a current meter?

A. No, I never did.

Q. You are connected with the Northwestern University School of Civil Engineering?

A. Yes, School of Engineering.

Q. Of engineering?

A. Yes.

Q. We have called it civil engineering; I do not know whether there is a difference?

A. That covers the whole field.

Q. I suppose there is a mechanical engineering department, something like that, is there?

A. It is all included within the same college; therefore it is called the College of Engineering, rather than Civil Engineering.

Q. Your institution has to do with hydraulics, hasn't it?

A. It has.

Q. Have you got a Haskell Meter at your College?

A. No, we have not.

Q. You have a Price Meter though, haven't you?

A. Yes.

Q. In analyzing and testing the accuracy of the discharge observations on the Niagara River, did you apply any criteria other than purely mathematical ones?

A. I did.

Q. Give us the details of what you applied, other than mathematical criteria?

A. I made a study of the details of the methods of observation and of computation that were used in connection with the measurements of discharge of the Niagara River, and other similar measurements.

Q. What did you apply in that study to prove the accuracy of the measurements, other than mathematical calculations?

A. I necessarily applied my knowledge of the methods. It was not simply a mathematical study. Necessarily, there are questions of judgment involved all the way through, in both the observations and in the methods of computation; therefore it is not purely—

Q. You used personal judgment as to making certain reductions there, did you?

A. Yes, sir, also judgment—

Q. When you say "methods of making the observations," you refer to the manner, the method followed in taking the discharge measurements?

A. Yes.

Q. That is you considered the various methods used, did you?

A. Yes.

Q. And then you formed an opinion as to whether the methods which were used in making those measurements were proper methods, did you?

A. Yes, were methods which would secure the facts.

Q. From a mathematical standpoint?

A. No, I should say from an engineering standpoint. That is, it is far from being purely mathematical, as it involves many other things than simply mathematics.

Q. Upon what did you base your opinion as to the method used?

A. On the various printed records and also, of course, the information given in the exhibits that have already been referred to in my direct testimony.

Q. You made a study of the methods used in making discharge measurements, for the purpose of testifying and forming an opinion as to the accuracy of that method, did you?

A. Yes, sir, I made a special study, of course of it, in addition to the general information which I had on the same subject, of course, before.

Q. You did not have any practical experience as to the use of the methods, did you?

A. No, not in the sense of having made any measurements myself.

Q. I hand you three sheets, blue prints, on which there appears certain figures, which blue prints I ask be marked Hayford's Exhibit A, cross examination. (Blue prints so marked.) This exhibit upon its face purports to show corrected discharge measurements of the Niagara River, Open and International Bridge Sections. Assuming these measurements to have been made under the same circumstances and

conditions as the 340 measurements concerning which you testified on direct examination, what do you find the mean discharge to be at elevation 572, and what do you find the increment to be for 1 foot change of lake level for the 340 of these measurements at elevations corresponding to those previously considered by you?

Mr. Hopkins: That question is objected to. It is not based upon evidence in this case, and will involve an unreasonable amount of time to work out, perhaps will require from ten to twenty days to answer; and therefore we will insist upon the objection. And instruct the witness at this time not to answer.

Mr. Adcock: The witness has attempted to qualify as an expert computor. We insist that this question is a proper question to test the witness' ability to make calculations, such as he attempted to make in his direct examination; and it has to do with ascertaining the methods of arriving at results from discharge observations, and the materiality of the opinion given by the witness in direct examination.

It is also suggested that this question was submitted to the counsel for the Complainant, and read into the record at a hearing some three or four weeks ago, so that the witness has been advised of the character of the question which would be asked, and has had an opportunity to make the calculations, and to answer the question which has been just now asked. The question was submitted on Wednesday the 15th of April.

Q. Will you now answer the question, Mr. Witness?

Mr. Hopkins: I will add to the record the statement of the fact that counsel for the Government notified counsel for the Sanitary District that they would not ask the witness to answer the question until the source of the figures was put in, and the facts upon which the question is based were made a part of the record. So far as that is concerned, I again instruct the witness not to answer at this time.

Mr. Adcock: In other words you now instruct the witness?

Mr. Hopkins: May I ask the witness another question, before that? (Q) Mr. Hayford, about how long would it take to answer that question; or could you answer it with any degree of accuracy?

A. I think it would take approximately 20 days, and so far as I understand this, it seems to me that then the answer could not be well founded unless there is more information furnished than is given on those sheets. I have not seen the sheets yet. There is not sufficient information, in my opinion,

given on those sheets to make it possible to return an answer corresponding to the answer in the direct testimony.

Q. What additional matters, Mr. Hayford, ought to be there?

A. The same information as to the methods of computation of these figures as is available in the case of the other figures. In the case of the other figures, the full information is given as to the method of computation leading up to the results. It seems to me to return an answer corresponding to the answers given in the direct testimony, I must have that full information in regard to these figures.

Mr. Adcock: Q. What computations do you refer to?

A. Computations connecting the observations made in the field with these figures, which purport to be the discharge at particular times. That information is given quite fully in the other case.

Mr. Hopkins: I wish to incorporate—

Mr. Adcock: Just a minute: Q. Have you read the question which has been put to you, and the assumptions that were to be made in connection with these discharge measurements?

A. I have; yes, I heard it.

Q. You observe you are to assume that the measurements were made under the same circumstances and conditions under which the 340 measurements were made, concerning which you testified on direct examination?

A. Yes, but the blue prints, these blue prints, of course are results; they are not the measurements. The measurements are the readings taken in the field; and it is the connection between the measurements actually made and these figures which purport to be discharges that is missing, in my opinion.

Q. In answering the question put to you with reference to 340 measurements, what field notes did you see?

A. I did not see any of the original field notes.

Q. Did you see any copies of field notes?

A. No.

Q. Then you necessarily did not take the field notes into consideration in arriving at your results testified to in your direct examination, did you?

A. No, I did not have the field notes.

Mr. Adcock: I submit for the record, in connection with this question, that in the course of the cross-examination of the witnesses, both for the complainant and the defendant, questions have been asked which have required the making of computations; and that this is the first time that any objection has ever been made upon that score.

I also submit that it is perfectly proper to ask an expert witness a question of this kind, a question which may require a considerable amount of work in connection with making the answer. Do I understand that the counsel for the Government still instructs the witness not to answer the question?

Mr. Hopkins: I wish to incorporate in my objections to the question the reasons given by the witness himself as to the impropriety of attempting to answer the question. I do still instruct the witness not to answer the question at this time, but will take the matter before the court at the most convenient time, and submit it.

Mr. Adcock: The defendant insists upon the witness' answering the question submitted. And for the purpose of the record, I want to state that upon an answer being given to the question which has been asked, I will ask two other questions based upon the same conditions: With what degree of precision is each certainly correct, and a further question: And within what degree of precision is it an even chance that the error of each is greater or less?

Mr. Hopkins: The same objection is made to the other questions, it being understood that as to all questions, there is still reserved the objection of materiality and competency. And I instruct the witness, in the same way, not to answer the two last questions, at this time.

Mr. Adcock: That is all, Mr. Hayford.

Re-direct Examination by Mr. Hopkins.

Q. When you said something was missing, Mr. Hayford, did you make it clear just what you meant, in regard to field notes, or just what did you mean?

A. What is missing in this data?

Q. In the question that is offered to you to-day.

A. Yes. In order to enable an opinion to be formed, the connection between the field notes on the one hand and these discharges, or what purport to be discharges on the other hand, that method of computation in detail is the thing which is the missing element.

Q. And without that, you do not think you could answer the question?

A. No.

Re-cross Examination by Mr. Adcock.

Q. I will amend the hypothetical question asked, and will ask you to assume that the discharges shown are the actual,

positive, certain discharges for the elevation shown. Then, Mr. Hayford, is there any reason why you could not make the computations which you are asked to make in that question?

A. It would seem to me that would beg the question. The discharge is the thing which must be measured. The question is the accuracy of the measurement. Therefore we must have the methods of the measurement, and of arriving at the figures, the final results from the measurements, in order to know what the accuracy is.

Q. Then you are assuming something which I have not asked you to assume in my question, aren't you?

A. No, I don't think I am.

Q. I am asking you to assume certain conditions here. You are an expert witness. Assuming that the elevation and the discharge were the two things that were observed, and that there were no intermediate steps.

Mr. Hopkins: In others words, you wish to bring in a matter purely of mathematical computation.

Mr. Adcock: Yes.

Mr. Hopkins: And we make the same objection, same instruction; further, that it is not fair to ask our witnesses to do computing for the Defendant.

Mr. Adcock: That is all.

FRANCIS C. SHENEHON, a witness recalled in rebuttal on behalf of the Government, having been previously sworn, testified as follows:

Direct Examination by Mr. Hopkins.

Q. Mr. Shenehon, you testified in this case, in June, 1909, didn't you?

A. Yes.

Q. Since that time, what have been your professional activities, connections and so on?

A. In September, 1909, I resigned from the Government service, and became Dean of the College of Engineering of the University of Minnesota, at Minneapolis.

Q. What is your work in that connection?

A. My work is mainly administrative, as Dean of the College. I am also head of the department of civil engineering and a lecturer to the post-graduate, the fifth year civil engineers on the subject of rivers, harbors and canals.

Q. Have you during that time been engaged in any private practice?

A. Yes, I have given a certain portion of my time to consulting practice as a civil engineer.

Q. You were an expert for the United States Government in the case of United States against the Chandler-Dunbar Power Company?

A. Yes.

Q. You have also been engaged as expert and have been working on this case have you not, Mr. Shenehon?

A. Yes.

Q. Just to what extent have you worked on this case?

A. I have given perhaps six months or more of my time, mostly in the last two years, to this case.

Q. Just in that connection, what in detail have you done in this case?

A. I have attended most of the hearings in which testimony has been taken. The testimony which I did not hear before the Commissioner, I have for the most part read. I have not read the testimony of the six masters of vessels that was recently taken. Aside from that I believe I have read all the testimony.

Q. Have you given any special study to the testimony in this case?

A. Yes, I have given very extensive study and consideration to the testimony in this case and to the elements entering into the hydraulic situation of this case, as well as other elements.

Q. In reading the testimony of defendant's witness, Williams, did you also read and study the exhibits that were put in evidence in connection with it?

A. Yes, I have given some considerable study to the exhibits, as well as to the verbal testimony of Mr. Williams.

Q. I show you chart market for Identification "Exhibit 3, Williams' Cross-Examination" and ask you to tell just what that chart is; what it shows; who made it and how?

A. This chart was made by me, and upon it are plotted 219 discharge observations made on the Niagara River at the International Bridge Section. In the vertical scale indicated on the left hand side of the chart is the elevation of Lake Erie as indicated by the Buffalo water gage. Plotted, and increasing towards the right is the volume of flow. The scale is shown at both the top and the bottom of the chart; the volume of flow in cubic feet per second, or the discharge in cubic feet per second.

The statement or title on this chart indicates that it is discharge measurements of the Niagara River plotted from the records of the U. S. Lake Survey. The measurements of 1898, 1899 and 1900, are shown by black circles, 101 measurements in all. The measurements of 1907 and 1908, are shown in crosses or with a plus sign. There are 118 of these measurements in 1907 and 1908.

The center of gravity, or the mean of all of these 219 measurements, is shown by a star. There are two lines threading these observations. I withdraw the word "two". There is one line threading these observations and a second line which I will refer to later. The line threading the observations was drawn by Mr. Gardner S. Williams, Advisory Expert to the Sanitary District in this case, and the method employed was to stretch a thread. This line was drawn by Mr. Williams, having in view the star representing the center of gravity of all observations.

Q. I believe you said Mr. Shenehon that this on its face purported to be a plot of observations made by the Lake Survey. You made it, didn't you, the plot?

A. The plot was made by me and was not made by the Lake Survey, but from the records.

Q. Is the plot what it purports to be?

A. Yes, and it has been very carefully checked, and I believe it to be accurate.

Now, the second line which does not thread the observations, but passes through the center of gravity represents a law of discharge in which the increment is 34,000 instead of what I believe to be the true increment of the Niagara River, 21,900.

Mr. Hopkins: I offer that document in evidence and ask that it be marked Shenehon's Exhibit A of this date.

(The document identified by the witness was marked Shenehon's Exhibit A, April 15, 1914.)

Mr. Hopkins: It was understood that a photograph will be substituted for this exhibit.

Q. I show you a chart marked "Haskell Exhibit 1, February 3, 1914," and ask you who made that chart and what it is?

A. This chart was made under my direction and corresponds in part with the chart just described, to the extent that the 219 observations before mentioned are plotted on this chart. These are all plotted in solid circles. The scale is the same as the chart just described.

Q. That is Shenehon's Exhibit A, of this date?

A. It also has a star, representing the mean volume of discharge and mean Lake Erie elevation for the 219 observations shown.

In addition, there is plotted, in the form of a black square, the mean of 121 measurements at the Open Section of the Niagara River.

There is also plotted, in the form of a black triangle, the mean of 10 measurements at the third or Split Section of the Niagara River. The equation of discharge indicated by the heavy black line threading the observations is indicated as $Q = 153{,}300 + 21{,}900\ (H_B - 570.00)$. In this equation the quantity or volume of outflow in cubic seconds feet is represented by "Q." "H" sub "B" indicates the height or elevation of the water surface of Lake Erie at the Buffalo gage. The increment of flow for a rise of 1 foot, is 21,900 cubic seconds feet.

The statement is made on this chart that the loss of level of Lake Erie for loss of outflow of 10,000 cubic seconds feet is 0.457 feet or 5 1/2 inches; for loss of outflow of 14,000 cubic seconds feet is 7 11/16ths inches.

Mr. Adcock: I did not know that that statement was on that chart. I object to it on that ground.

Mr. Hopkins: Q. Is that shown on the chart?

A. That is shown on the chart, yes.

Mr. Adcock: Have you offered it in evidence?

Mr. Hopkins: No, I have not offered it in evidence.

Mr. Adcock: All right.

The Witness: On the right hand side of the chart are certain lines with indicated Lake Erie elevations in figures at the left of it. The uppermost of these indicates the mean Erie level at Cleveland for June, 1908. And is so stated on the plot.

It is further stated that 10 observations for discharge volume are shown thus: The symbol to the right of "thus," being a solid circle. The other lines and solid circles indicated are self explaining. The object of this was to make a detailed study of the observations themselves by utilizing a blueprint with various colors shown on the circles indicating the observations.

Mr. Hopkins: I offer that chart in evidence as Shenehon's Exhibit B, of this date.

(Whereupon document referred to was marked Shenehon's Exhibit B, April 15, 1914.)

The Witness: I wish to make one additional explanation:

In addition to the heavy black line threading the observations are three lines on either side. These lines indicate the limits of the percentage variations of volume of flow. This is stated on the lines themselves, and I believe is self explaining.

Mr. Hopkins: I renew the offer.

Mr. Adcock: As I understand, the statement as to the effect of a diversion of 10,000 and 14,000 cubic feet per second as appears on that chart is a mere statement of what the chart itself shows that to be, isn't it?

The Witness: The lowering for Erie, as indicated on this chart, is based upon the assumption that the increment indicated, 21,900, is the correct increment.

Mr. Adcock: And the statement of the lowering of the levels of Lake Erie is simply a conclusion from that chart itself. In other words, in admitting this in evidence, we do not want to agree that that is the actual lowering. The words there that are used as to stating the effect of the diversion of different amounts on the lake levels is a statement as to what that chart itself shows.

The Witness: Let me just add something.

Mr. Adcock: Yes.

The Witness: I wish to state further that the increment indicated on this sheet and the line representing the law of discharge are the same as the increment and line on U. S. Exhibit number 3, introduced earlier in this case. And the conclusions drawn from that increment are the same as indicated by the scale on the left-hand corner of that earlier exhibit.

Mr. Adcock: This statement here: "The loss of level of Lake Erie for loss of outflow of 10,000 cubic seconds feet, is 5¼ inches; for a loss of outflow of 14,000 cubic seconds feet, it is 7 11/16ths inches," that is a conclusion from the chart itself, isn't it; that is what the chart shows?

A. It is a conclusion drawn from the observation and demonstrated by the chart itself, and in my judgment is a correct deduction.

Mr. Adcock: I want to object to the offer of that on account of the statement which is made on the chart, unless it is admitted by the Government that the statement as to the effect of the diversion is simply a conclusion from the chart itself.

Mr. Hopkins: I understand that the statement as to the loss of level of Lake Erie, as it appears on the chart, is a

result or a conclusion from the results obtained from the chart itself.

Mr. Shenehon: That is true.

Mr. Hopkins: All right.

Q. I show you another chart marked Shenehon's Exhibit C for Identification of this date. Will you just tell who made that chart, Mr. Shenehon; what it is and what it shows?

A. This is a chart on which certain selected discharge observations of the Niagara River are plotted on the same scale as to lake elevation and as to volume of discharge as Exhibit B, just indicated.

Mr. Adcock: That applies to Erie?

A. It applies to the Niagara River at the International Bridge Section.

Mr. Hopkins: Q. Just what observations are plotted there?

A. 30 observations, selected by Mr. Gardner S. Williams, Advisory Expert of the Sanitary District in his study of the Niagara River, are plotted in solid black circles. In addition, in solid triangles, are plotted 10 observations of discharge of the Niagara River taken in the winter season when ice conditions prevailed.

Q. What do the lines show?

A. The heavy central black line threading the solid circles indicates the law of discharge the same as on Exhibit B, using the same equation, which involves also the same increment 21,900.

A statement is made on this chart below the title: 30 measurements selected by Mr. Gardner S. Williams, expert witness, on behalf of the Sanitary District, from a total of 101 measurements in 1898 and 1899, shown thus: That is the solid black circle. It further states: Mr. Williams neglected 118 measurements in 1907 and 1908, and by oversight included 10 winter measurements when ice conditions prevailed. These are shown thus: the symbol being a triangle. The increment used by U. S. is 21,900.

Q. Just what does that chart show?

A. This indicates that out of 219 observations available, Mr. Williams selected 30, as representing the most quiescent conditions, as he saw them of Lake Erie, and as I have before stated the ten observations during the winter, which crept in by oversight.

A point I wish to make in presenting this exhibit is that if an increment be drawn from the 30 observations selected by

Mr. Williams, it will be less than 21,900. If the quiescent observations are the ones from which we should determine the increment, an increment drawn through the 30 selected by Mr. Williams will be less than 21,900; I should say as little as 21,000. I have not computed it.

Q. Does that include the ten winter observations?

A. No, that excludes the ten winter observations. In Mr. Williams' earlier testimony on this subject, which was the basis as I understand it of the testimony of Mr. Freeman and Mr. Stearns, the winter observations were used and an aggravated or enlarged increment determined by reason of that, and by reason of other erroneous, as I see it, methods of reduction.

Mr. Hopkins: I offer that chart in evidence as Shenehon's Exhibit C of this date.

(Chart offered in evidence was marked Shenehon's Exhibit C, April 15, 1914.)

The Witness: I should state that this was made under my direction and has been very carefully checked.

Mr. Hopkins: Q. I now show you another chart, Shenehon's Exhibit D, of this date, which is also marked Hayford's Exhibit 7, for Identification, April 10, 1914, and ask you the same questions in regard to that chart?

A. This is a chart of the discharge observations at the Open Section of the Niagara River. The scale is the same as already described for Exhibits A, B and C. 121 measurements taken in 1899 and 1900, are shown by solid black circles. In addition, the 219 measurements of the flow of the Niagara River at the International Bridge Section are shown by a solid square; and the ten measurements taken at the Third or Split Section of the Niagara River are shown by a solid triangle.

The solid heavy line threading the observations indicates the law of flow, as shown by the observations. This line passes through the mean of all the observations, which is indicated by a star as on the other exhibits A and B, already described. The lines on either side of the heavy black line show the limits of the percentage variation from the law indicated by the heavier line. Certain statements concerning the elevation of the lake for the individual observations, or for the groups of observations for months, are indicated on the right-hand side much the same as in Exhibit B.

The equation of discharge indicated on this chart is: $Q = 151{,}000 + 21{,}640\ (H_B = 570.00)$. The meaning of the

terms used, Q and H_B, are the same as indicated for Exhibit B.

Q. Was that made under your direction and checked?

A. This chart was made under my direction and has been very carefully checked and I believe it to be accurate.

Mr. Hopkins: I offer it in evidence as Shenehon's Exhibit D, of this date.

(Chart offered in evidence was marked Shenehon's Exhibit D, April 15, 1914.)

The Witness: This contains a statement of the loss of level indicated by the increment used, which is 21,640.

Mr. Adcock: That is as shown on that chart?

The Witness: Deduction from the increment.

Mr. Adcock: As shown on the chart.

The Witness: As shown on the chart.

Mr. Hopkins: Q. I now show you this chart, Shenehon's Exhibit E, of this date, which is also Hayford's Exhibit 6, of April 10, 1914, and ask you the same question in reference to this chart.

A. This is a chart which contains two different illustrations. On the left-hand side is given the volume of discharge of the Niagara River plotted with respect to the elevation of the water surface at the Suspension Bridge. This is in the gorge of the Niagara River, this gage, just above what are known as the Whirlpool Rapids, in the still, deep water at that point. The scale on the left hand indicates the elevation of the water surface in feet and hundredths. And the scale at the top indicates the volume of discharge in cubic seconds feet. The solid black circles indicate groups of discharge observations. Each of these groups contains four observations and these four observations were each made on a single day. This is in a way selected observations, because no day was utilized that had less than four observations. These observations are those already in evidence, made at the International Bridge of the Niagara River, in 1907 and 1908.

The black open circle shows the center of gravity or mean of the 16 groups, containing 64 discharge observations altogether. The solid line threading these observations indicates the law of discharge, or the relation between the water surface elevation and the volume of flow; and the equation at the bottom of the plot indicates this relationship.

Q. Was that chart made under your direction?

A. This chart was made under my direction, and has been very carefully checked and I believe it to be accurate.

A statement is made at the bottom showing that the derived increment for Lake Erie is 21,860. On the right-hand side of the chart is a similar plot for the water surface in the whirlpool of the Niagara River. 60 observations are used in this and the groups are of 4 observations each; each of the four observations being the work of a single day.

Mr. Hopkins: I offer that chart in evidence as Shenehon's Exhibit E, of this date.

(Chart offered in evidence was marked Shenehon's Exhibit E, April 15, 1914.)

The Witness: The increment as deduced for Lake Erie from Whirlpool gage is indicated as 22,440.

Q. I now show you a chart, Shenehon's Exhibit F, of this date, which is also marked Ray's Exhibit 2, of February 4, 1914; and ask you to tell under whose direction it was made, and what it shows?

A. This chart was made under my direction, and has been very carefully checked. It shows the volume of discharge of the Niagara River, plotted with respect to the elevation of the water surface in the Gorge at Suspension Bridge. It differs from the Exhibit E, in the fact that it utilizes the 118 observations available and printed in the document known as the "Preservation of Niagara Falls."

Q. What increment is derived from that?

A. The increment for Lake Erie at Cleveland deduced from this chart and from certain data referred to in this chart is 22,000 cubic second feet.

Mr. Hopkins: I offer that in evidence as Shenehon's Exhibit F, of this date.

(Chart offered in evidence, marked Shenehon's Exhibit F, April 15, 1914.)

Q. I show you chart, Shenehon's Exhibit G, of this date, also marked Ray's Exhibit 3, of February 4, 1914, and ask you to tell us under whose direction that was made and what it shows, what it is?

A. This chart was made under my direction and very carefully checked. It is similar to Chart F, just described, except that the water surface to which the volume of flow is referenced is that at the Whirlpool gage in the Whirlpool of the Niagara River. The increment deduced for Lake Erie is 22,400.

This is 108 observations taken in groups of ten, except that one is taken in a group of eight. The data used in making this chart is indicated in a table at the upper left hand corner.

Mr. Adcock: Q. Is there any statement of the lowering effects there?

A. Yes.

Q. I assume the statement is simply a conclusion from that chart, isn't it The same admission is made with reference to that statement that was made with reference to the other?

A. Yes, sure.

Mr. Hopkins: I offer this in evidence as Shenehon's Exhibit G, of this date.

(Chart offered in evidence was marked Shenehon's Exhibit G, April 15, 1914.)

Q. I show you chart marked Shenehon's Exhibit H, of this date, also marked Ray's Exhibit 1, of February 4, 1914, and ask you the same questions in regard to that?

A. This is a chart showing two different lines, with the observations plotted in solid black circles, which would determine the trend and position of these lines. The scale on the extreme left hand side shows the elevation of the water surface at the Suspension Bridge in the gorge of the Niagara River already referred to.

The scale on the right hand side indicates the elevation of the water surface at the Whirlpool gage in the Niagara River. The scale crosswise of the chart as indicated, indicates the elevation of the water surface at Cleveland, at the water gage of the United States, at Cleveland. The lines indicate the relation or law of fluctuations; the left hand one, the movement of the water surface in the gorge of the Niagara River, for a foot change, or for any change of Lake Erie; and the one on the right hand side, the similar relation for the Whirlpool.

This is derived from monthly mean observations as indicated by the tabulation of data in the extreme left hand corner and the right hand side above the title.

The conclusion reached from this data and from this chart is that the water surface at Suspension Bridge has a movement of 2.334 for a change of 1 foot of Lake Erie surface at Cleveland, considered as monthly means; and that the water surface in the Whirlpool has a movement or fluctuation or change of 2.661 for a foot change at Cleveland, as determined by monthly mean elevations of these water surfaces.

This chart has been used in connection with Exhibits F and G, in deriving the increment of the Niagara River with reference to the water gage at Cleveland. These three charts

reach an increment of the Niagara River in entire accord with the previous increment, at the same time eliminating completely any use of the Buffalo gage.

Mr. Hopkins: I offer the chart in evidence as Shenehon's Exhibit H, of this date.

(Chart offered in evidence was marked Shenehon's Exhibit H, April 15, 1914.)

Q. I show you a chart marked Shenehon's Exhibit I, of this date and ask you the same question in regard to that that I have as to the others?

A. This was made personally by me and has been carefully checked. It represents the relative fluctuations of the water surfaces of Lake Huron at Harbor Beach and Lake St. Clair at the Flats. Each observations shown by a solid circle which indicates the mean elevation of the water surfaces referred to for the months June to November, inclusive, each year. The mean of the 24 groups is shown as a star. The line threading these observations is the law of relationship between these two water surfaces of Lake Huron and Lake St. Clair as indicated by the United States Lake Survey, in its report of 1912, page 3546.

Q. Has that chart been used in this record before?

A. This chart was used in the cross-examination of Mr. John R. Freeman, and possibly other witnesses.

Q. Do you know whether it was marked for Identification at that time?

A. It was used in the form of a blueprint on which a certain number of observations after 1889 were colored red, so as to show a distinction between those prior and those after. It was used in investigating the matter of any possible change in the regimen of the St. Clair River.

This was used in the cross-examination of John R. Freeman as Exhibit 13, October 8, 1913.

(Chart identified by witness was marked Exhibit I, April 15, 1914.)

Q. I now show you a chart, Shenehon's Exhibit J, of this date and ask you the same questions in regard to that.

A. This was used in the cross-examination of Mr. Freeman in the form of a blueprint and was marked at that time U. S. Exhibit N.

Q. Who made this chart?

A. This was made under my direction and indicates the relative water surface elevations of Lake Erie at Cleveland and Lake Ontario at Oswego. The solid black circles repre-

sent the annual mean elevations prior to and including the year 1903. Beginning with the year 1904, and all other years up to the year 1912, the observations are shown by solid red circles.

This chart is designed to show the characteristic change in the relationship of Lake Erie and Ontario coming with a definite known change of regimen in the St. Lawrence River, due to the building of the Gut Dam. A black line threads the observations for mean elevations for the years prior to 1904, and a red line after that time.

Mr. Hopkins: I offer that chart in evidence as Shenehon's Exhibit J.

(Chart offered in evidence was marked Shenehon's Exhibit J, April 15, 1914.)

Q. I show you four photographs of charts, Shenehon's Exhibits K. L. M and N of this date, which were referred to in the cross-examination of Gardner S. Williams, and marked respectively Complainant's Exhibits F, G, H and I; and ask you to state under whose direction these were made and what they show?

A. The original charts of which these are photographs were made under my direction, and every pains taken to ensure their accuracy. This series of charts has been referred to in this case as the Three Curve Series, and consists of four sheets marked 1, 2, 3 and 4. These sheets show the observations of discharge for the Niagara River taken in the years 1907 and 1908, 118 observations in all. These observations are plotted in solid black circles on a scale of volume in cubic second feet.

The waving dotted line which passes near or through these observations in this is the center of the three continuous broken lines shown on each sheet, indicates the computed volume of flow from the water surface elevation at the Buffalo gage, Lake Erie.

Q. Using what equation?

A. The equation used is stated on each of these sheets and is the same as that used in U. S. Exhibit 3; also the same as that used on U. S. Exhibit, Shenehon's B and C of this date.

The upper waving line indicates the elevation of Lake Erie at the Buffalo gage as shown by the scale on both the left and right-hand sides. This is plotted for each hour of the day and is the basis of the volume of flow indicated by the dotted line.

In other words, knowing the elevation of Lake Erie at Buf-

falo, and having an equation which will give us the discharge or volume of flow, the dotted line indicated is easily represented.

The bottom waving line on these sheets indicates the elevation of the water surface in the Gorge pool of the Niagara River at Suspension Bridge gage. This is also plotted for each hour of the day. The information given by this series of sheets is very considerable, and the use of the waving line at the Suspension Bridge gage gives very definite conclusions as to the time which it takes a change in Lake Erie to travel the distance between the Gorge pool and the Buffalo gage; or, conversely, the Buffalo gage and the Gorge Pool.

Q. What does it show that time to be?

A. Rather elaborate investigation of this matter indicates that the lag or time of travel of the crest or the valley between the Buffalo gage and the Gorge Pool is about three hours and a quarter.

Mr. Austrian: How far is it?

A. The distance is approximately 25 miles.

A. I wish to state that in the original blueprint used in this case, one observation was not plotted. It was omitted and a third checking of the series revealed its absence. It has since been plotted on the original and is reproduced in these photographs. That refers to the observation first on August 5th. The scales and other matters connected with these sheets, I believe are self-explanatory.

Mr. Hopkins: I offer these in evidence as Shenehon's Exhibits K, L, M and N, of this date.

(Documents so offered in evidence were marked Shenehon's Exhibits K, L, M and N, April 15, 1914.)

Q. I now show you three charts marked Shenehon's Exhibits O, P and Q of this date, which were also used in the cross-examination of Gardner S. Williams, and which have been referred to by various witnesses in this record as Complainant's Exhibits J, K and L, and ask you to state who made them and what they show?

A. These three charts or photographs are from original charts made under my direction, sheets 1, 2 and 3. These sheets have been referred to in this case as the One Curve Series. The waving dotted line indicated shows the water surface elevation of Lake Erie at the Buffalo gage. It shows at the same time by the relationship or equation previously referred to and used in the Three Curve Series, the discharge observations made at the Open Section in 1899 and 1900. This

series utilizes only those observations where we had a self-registering gage to give us the elevation of Lake Erie at Buffalo. This is beginning on August 30, 1899.

A statement is made on sheet number 1, of this series, and applies to the three sheets, that these observations on the Open Section have been adjusted so as to show the equivalent volumes as measured on the International Bridge Section.

By this I mean to say that to each observation taken in the Open Section, the values indicated on the lower right-hand corner of Sheet number 1, have been added. In plotting the continuous dotted line, the hourly elevations at the Buffalo gage have been utilized. This shows very definitely the change of Lake Erie level at Buffalo prior to and during the taking of the discharge observations, as well as after the taking of the discharge observations.

Mr. Hopkins: I offer those in evidence as Shenehon's Exhibits O, P and Q of this date.

(Documents offered in evidence were marked Shenehon's Exhibits O, P and Q, April 15, 1914.)

Q. I now show you a chart marked Shenehon's Exhibit R, of this date, referred to in the cross-examination of Gardner S. Williams, as Complainant's Exhibit A, and ask you to tell us who made it?

A. This was plotted under my direction and carefully checked.

Q. State what it shows?

A. It shows in broken lines the annual or yearly mean elevations of Lakes Michigan-Huron, Lake Erie and Lake Ontario. These are the solid black lines shown as a series of steps in the three profiles of the chart; the top one being Michigan-Huron, the middle one Erie and the lower one Ontario. The gages utilized are for Michigan-Huron, Milwaukee, Erie, Cleveland, and Ontario, Oswego.

At the right-hand side is shown the same form of profile except that the observations of elevations are grouped in five-year means, except the last period 1910 to 1912, which is of three years. At the right-hand side of each of these is a pronounced scale of inches.

Referring to the top profile on this chart, there appears certain dotted horizontal lines. These indicate the elevation of Michigan-Huron computed from the elevations for Lake Erie, as shown on the middle profile. The equation by which this is computed is indicated on the chart.

Where the actual or observed elevation of the lake is above

the computed elevation, the areas between the solid black line and the dotted horizontal line are shown in blue. Where the observed elevation of the lake is below its computed elevation this area is shown in red. The significance of the red may be that when the lake is lower than it is computed to be, it is dangerous.

A similar procedure is shown in the middle profile and for the bottom profile. Lake Ontario in the bottom profile shows, computed elevations from Erie by an equation indicated and the computed elevations for Lake Erie are derived from the elevation of Lakes Michigan-Huron. This has been referred to in this case as the red and the blue chart.

Mr. Adcock: Can you produce a letter written by Mr. Shenehon to Mr. E. E. Haskell, who was principal assistant engineer of the Lake Survey, written in 1899, or about that time?

Mr. Shenehon: Yes, the Lake Survey has got that. I told them it was all right to put it in.

Mr. Adcock: It was about 1899, in which there are some criticisms made by Mr. Shenehon of the measurements of the Niagara River. We have asked—Mr. Williams has asked for a copy of that letter, and I understand it has not been produced. We would like to use it in cross-examination of Mr. Shenehon.

Mr. Hopkins: I will answer in the morning.

Mr. Adcock: I understood it was referred to the United States Attorney here whether we could have a copy. The request was made about the 23rd of March, this year.

Mr. Hopkins: I offer in evidence this chart as Shenehon's Exhibit R, April 15, 1914.

(Chart offered in evidence marked Shenehon's Exhibit R, April 15, 1914.)

Adjourned to Thursday, April 16, 1914, at 10:00 o'clock A. M.

April 16, 1914, 10:00 A. M.

Parties met pursuant to adjournment.

Present same as before.

FRANCIS C. SHENEHON, resumed the stand and testified further on direct examination as follows;

Mr. Hopkins: Q. I now show you a chart marked Shenehon's Exhibit S, April 15, 1914, also marked Government's Exhibit O, for Idenification, and referred to in the cross-examination of Frederic P. Stearns, and ask you to tell what that chart is and what it shows?

A. This chart is a record of the United States Lake Survey and contains three curves, two being or representing the laws of discharge of the St. Lawrence River for the period prior to the building of the Gut Dam, and the other for the period after the building of the Gut Dam on the St. Lawrence River. These are discharge curves of the St. Lawrence River. The discharges plotted on this sheet are with respect to the water level of Lake Ontario at Oswego as represented by a scale on the left-hand edge of the sheet.

On the right-hand side is also a scale of the water surface elevations at Ogdensburg, so that the volume of flow may be taken off for either the elevation of Lake Ontario or the elevation of the St. Lawrence River at Ogdensburg. The third curve is the discharge of the St. Lawrence River referred to the depths on the old sill of lock number 25, which as I recollect it is at the foot of the Galops Canal.

The title and explanation in the lower right-hand corner indicates that this was made in 1912, by Mr. Sherman Moore, Junior Engineer; and that it was compiled under the direction of Lieutenant Colonel C. S. Riche, Corps of Engineers, U. S. A.

Mr. Hopkins: I offer the chart in evidence as Shenehon's Exhibit S, April 16, 1914.

(Chart offered in evidence was marked Shenehon's Exhibit S, April 16, 1914.)

Q. I now show you a table, Shenehon's Exhibit T, of this date, which is referred to in the cross-examination of John R. Freeman as United States Exhibit M. I will ask you who

made that table, what it is, and from what sources it was made?

A. This was made by me personally, and is an analysis of the consistency of the flow of the St. Lawrence River as compared with the flow of the Niagara River for 16 years, beginning in 1891, and ending in 1906. The table itself indicates the sources of the data. The St. Lawrence River outflow was taken from the curves shown on Shenehon's Exhibit S, which was at that time the best available data in my judgment as to the outflow of the St. Lawrence River. Perhaps I should make the reservation: The best available compiled data. At that time, some additional observations had been taken on the St. Lawrence River, but not reduced.

The flow of the Niagara River is taken from United States Exhibit Number 3, and to that, as indicated by the tabulation itself, 2,300 cubic seconds feet has been added for the flow of the Niagara River, on account of the Erie and Welland Canals.

The local supply and storage for Ontario is taken wholly from the tabulation of Stearns Exhibit Number 1.

The conclusion indicated by this table is that the Niagara River and the St. Lawrence River are in accord within 4,600 cubic seconds feet, or about two per cent.

Mr. Hopkins: I offer that table in evidence as Shenehon's Exhibit T, of this date.

(Table offered in evidence marked Shenehon's Exhibit T, April 16, 1914.)

The Witness: I think I should state that this indicates that the actual discharge of the Niagara River as computed from discharge measurements is less by 4,600 feet than deduced discharge; the deduced discharge in this case being that derived by taking the observed flow of the St. Lawrence, as computed from the discharge measurements of the St. Lawrence, and subtracting from it the local supply and storage for Ontario, as shown by Mr. Stearns in his Exhibit 1. It may also show that the volume of flow of the St. Lawrence is too great by two per cent., or any combination of errors in the local supply and the discharges of the two streams, which will serve to bring about this result.

Q. Now Mr. Shenehon, I show you some papers, Shenehon's Exhibits U1, U2, U3, U4 and U5, which are also marked Hayford's Exhibits 1, 2, 3, 4 and 5 for Identification, April 10, 1914; and ask you to state who made those and what they are?

A. This is a computation by Mr. Williams' three-point method of the law of discharge indicated by the 219 measurements of discharge of the Niagara River at the International Bridge Section. This computation was made by me personally and was checked by my assistant, and later in the cross-examination of Mr. Williams was referred to him for confirmation of the correctness of the computation, and the result derived, and returned as O. K. by him.

The conclusion is stated in the evidence, in Mr. Williams' cross-examination, and this shows that the increment of the Niagara River at the International Bridge is 21,860, as derived by this computation, while the Government's Exhibit Number 3 indicates an increment of 21,900.

Mr. Hopkins: I offer those sheets in evidence as Shenehon's Exhibits, U1, U2, U3, U4 and U5.

(Sheets so offered in evidence were marked Shenehon's Exhibits, U1-U5, April 16, 1914.)

Q. You say you have read and studied the testimony of Gardner S. Williams, Frederic P. Stearns and John R. Freeman in regard to methods of determining increments for the St. Clair, Niagara and St. Lawrence Rivers, Mr. Shenehon?

A. Yes, sir.

Q. And their conclusions and opinions as to those increments?

A. Yes.

Q. Will you just state in a general way the method used by those witnesses in determining an increment; and comment on it?

A. In the derivation of the increment of the St. Clair River, Mr. Gardner S. Williams used a variety of methods. Starting with the groups utilized in the U. S. Exhibit Number 1, Mr. Williams makes reduction by the method of three points instead of the method of least squares. This has the effect, as I recollect it, of slightly increasing the increment. I may state here, however, that the method of three points as opposed to the method of least squares makes no large difference in any conclusion reached in this case for the increment, no large difference.

I wish to state in passing also that the increment as shown on U. S. Exhibit Number 1, which is a discharge curve of the St. Clair River, was computed by the method of least squares and was not gotten by the stretching of a thread or string. So far as the use of the three-point method, or least squares is concerned, or even the method of stretching a thread, the

indications of the increment, of the Niagara River, as an illustration, shows that the line shown on U. S. Exhibit Number 3, giving an increment of 21,900, differs but slightly from the increment derived by the three-point method as used by Mr. Gardner S. Williams; the latter being 21,860.

Mr. Williams in stretching a thread over the observations at the International Bridge of the Niagara River determines an increment of 21,600. It would appear that whatever method is used in determining the increment from the observations in the three cases of the St. Clair, the Niagara and the St. Lawrence, has little bearing on the issues in this case in my judgment.

A reservation should be made to this statement, that when you leave the straight line equation and begin to deal with curves, the three-point method no longer applies, and Mr. Williams' own statement in his testimony is that the method of least squares under these circumstances is the best method used.

I might add that in the case of the Niagara River, the very close check between the use of the three-point method and the method of least squares and the stretching of a thread comes from the fact that there is such a multiplicity of observations, and such excellent accord, that it does not make much difference what method you use in deriving the line indicating the law of discharge. I should add moreover that the range of four feet makes the trend of this line unquestionable within five per cent.

Now I have departed somewhat from the matter of the derivation of the increment of the St. Clair River by Mr. Williams. Mr. Williams then goes into the matter of the inclusion of the discharge work of the year 1901, which was not utilized in the computation of the increment of the St. Clair, as shown on U. S. Exhibit Number 1.

Mr. Williams corrects the observations of 1901 for the backwater effect or the lack of backwater effect of Lake St. Clair, and makes a computation in which he uses these. I do not know whether it is necessary for me to go into detail and indicate the increments derived by Mr. Williams.

Q. Not all of them, just the general method, and then in detail as to the one that he finally gives as being the correct one in his opinion.

A. Mr. Williams then gets out increments by the method of taking sets of observations in which Lake St. Clair is reasonably constant in stage, while Lakes Michigan-Huron is va-

rying, and in that way he determines, or attempts to determine an increment for the St. Clair River due to the stage or elevation of Lakes Michigan-Huron alone.

Mr. Williams then reverses the process, and taking reasonably constant elevations of Lakes Michigan-Huron, he finds what the effect, or attempts to find what the effect of the level of Lake St. Clair is in retarding or accelerating the outflow. While this method, which I believe was employed by Mr. Sabin, and I myself accept as a method of deriving increments, the application and detail of computation used by Mr. Williams are in my judgment not defensible.

I think I might refer to the table, in which Mr. Williams shows his derivation of individual increments, and in his summation and mean.

I wish to refer to Table 25, in Williams' Exhibit 34, in which he is discussing, by the method already stated, the increment of the St. Clair River for the changes in the elevation of Lake Huron at the head of the St. Clair River. These are from the observations of 1908 and 1910. The first increment derived utilizes as the data three discharge observations and the mean elevation of Michigan-Huron by the three discharge observations is 580.34. The center of gravity—or the elevation of one of the observations is evidently 580.32, and the extreme range of Huron level indicated by the center of gravity of the three points considered is .03 of a foot.

The second derivation of increment in the same table—

Q. Just on that one, what effect does that range or lack of range have upon the result?

A. I think no engineer, even Mr. Williams, would wish to state that there was any consequence whatever in an increment derived with a change of lake elevation of .03 of a foot.

Q. Why not?

A. The precision of the increment is proportional, other things being equal, to the range in the level of the lake between the observations. If one should take a set of observations with ten in each group,—two sets of observations with ten in each group, and there was a foot difference in elevation in the lake stage between the two, the error in the increment would be likely to be as much as ten per cent. or more; and where you took only .03 of a foot instead of a foot, why the increment is likely to be several hundred per cent. in error. By taking a large number of stages, the error in the result would be considerably diminished, but the method in

my judgment, the method of applying this treatment is not the proper one.

Q. That is because any error in your observations referred to that small range of stage would give a much greater percentage?

A. Yes. I wish to point out that in the increments derived by Mr. Williams in this table number 25, they range all the way from 7,500 up to 74,060.

In other words the range of the deduced increment itself, in the latter case, is nearly 10 times the increment derived in the former case. The variation of the increments derived by this method is all the indication necessary that the method itself is a trivial one. When I say that I mean the treatment, as Mr. Williams has given it.

On the following page, table 26, of the same Exhibit 34, the backwater increment for Lake St. Clair is indicated, and I find that in some of his derivations here, the increment is plus instead of minus. By this I mean that when Lake St. Clair rises, it increases the volume of outflow of the St. Clair River, which is contrary to all hydraulic laws, and contrary to Mr. Williams' own conclusion in the case. These increments vary, the backwater increments of Lake St. Clair, from 15,830 with a plus sign to 90,000 with a negative sign. This range of the derived increments is sufficient indication of the weakness of the method pursued.

I have mentioned only two of the tables in which Mr. Williams has used that particular treatment, and those did involve the observations of 1908 and 1910. In earlier tables he uses a similar treatment for the observations of 1899 up to the observations of 1908 and including the observations of 1908.

In table 22, Mr. Williams uses the observations of the years just mentioned and I note that his extreme range in one set of observations—and when I say extreme range it is the range of the three points in the three-point method of reduction—is 12/100ths of a foot. That is the top line of table 22, with 15 observations utilized. In a group of four observations in the middle of this table, the range between the extreme groups of the three-point method is 12/100ths, again.

Q. In general, I understand Mr. Shenehon, that Mr. Williams got an increment for the St. Clair by a certain method; another one for the Niagara and another one for the St. Lawrence; and then starting with those increments, checked them or re-determined, starting from one to the other by what is called the consistencies or inconsistencies of the rivers, the

ratio of fluctuations, taking into consideration local supply, and reached a final conclusion a little different from the one he had started with. Is that correct in general?

A. You refer to the method of fluctuations, what has been called in this case method of fluctuations, passing from one river to another, to determine an increment.

Q. Yes. But he first got certain increments in the way you have stated it?

A. I had not completed my statement in that particular.

Q. He first got some increments from the measurements themselves, didn't he?

A. Yes.

Q. You were engaged in explaining how he got his increments in the first place, to start with?

A. Yes.

Q. All right.

A. I believe the method that Mr. Williams finally concluded as the best method for his purposes, because he utilized it in the case of the Niagara and the St. Lawrence as well as the St. Clair was the method of taking groups of observations selected at times when the conditions were quiescent, or at least his attempt was to select groups of observations at quiescent periods of the lake.

Now, in carrying out this method on the St. Clair River, Mr. Williams selected 12 different periods; and combined the observations for the mean lake level of Michigan-Huron and St. Clair for each of the periods concerned, except that he advanced the date of the St. Clair observations for elevation or level of the lake by one day.

Mr. Williams in addition to that weights the observations, in proportion to the time interval between the observations as observed. For the earlier period prior to 1908, I believe it is, in these 12 groups, Mr. Williams selected 80 observations. By this method of weighting, he created four more observations making what he calls the weighted observations 84. Now this method of treatment assumes that the flow in the river, as I understand it, is so uncertain and so much out of equilibrium that it is necessary to take a considerable number of days in order to have static conditions, or conditions of even flow.

The fact however, as indicated by the observations themselves, is that the flow in the river is determined by the elevation of the lake at the head of the river at the time of the observation, or a few minutes preceding that time. This is

clearly demonstrated in the observations of the St. Clair River and in the observations of the Niagara River.

The method used assigns as part of the reason or cause of the flow in the St. Clair River a certain number of hours in advance of any individual observation or a certain number of hours after that particular observation, and the effect of this is to flatten out the elevation of the lake surface, which really controls the discharge. In other words, when we are observing for discharge, the lake varies to some extent on either side of what may be the mean level of the lake at that particular time. There will be some observations for flow in which the lake is above its mean level, and some observations in which the lake is below its mean level. Now, for the top or group of highest elevation, the effect is this: That the volume of discharge is referred to an elevation which is below the elevation of the lake which created it, and for the bottom observation, the bottom group of observations, the lake is referred to a mean elevation which is above the elevations which really created the discharge.

Now, I have not as a matter of fact analyzed the grouping in the St. Clair River, and what I speak of now refers more particularly to the Niagara River. The effect of this is to keep the volume of flow as observed by the United States Lake Survey while decreasing the change of lake elevation between. That is it diminishes, lessens the divisor in the fraction by which we determine the increment; the increment being the difference in volume of flow dvided by the difference in lake elevation. Of course this has the effect of making the increment appear larger and making the loss of level due to any diversion in the lake less.

Now, Mr. Williams' treatment of Lake St. Clair by advancing it 24 hours, I think has no bearing on the case, no tangible bearing on the case and his method of beginning at midnight for instance on the day on which his group of observations begins, puts in at least eight hours of Lake Huron elevation, which has no bearing, in my judgment, on the volume of outflow.

I wish to speak a little bit more about Mr. Williams' method of weighting observations. Mr. Williams gives a weight of unity, or one, to the observation of a single day, whether there are five observations on that day or whether there is one. That of course is destroying observations. On the other hand, if he happened to have an observation on Saturday and Sunday comes along and there are no observations there,

possibly none on Monday but there are some on Tuesday, then because there has been a time interval between these particular single observations, a time interval which has been included in determining the element, he gives a reward of merit to these observations for the falsification which has been put into them. In other words he has used something that has nothing, in my judgment, to do with the discharge, and rewarded the observations by giving them increased weight. In other words creating observations in the same process.

I see no justification whatever for a treatment of that kind. Now, Mr. Williams reaches by this particular method of reasoning and computing, a conclusion that the increment for the St. Clair is in the neighborhood of 29,000 cubic seconds feet.

Q. Is that same general method used in all the rivers, by Mr. Williams?

A. I wish to go into the difference in method in the Niagara and St. Lawrence a little more. And in his final testimony, Mr. Williams states his best judgment that 29,000 is the best increment for the St. Clair as applying to the issues in this case, and that it may be ten per cent. greater than that.

I wish to show what this method of weighting, what it actually amounts to in Mr. Williams' treatment of the 1908 and 1910 observations. He makes seven groups out of those observations. Mr. Williams starts with 161 observations, and by his method of weighting he destroys 88 of them and finally utilizes 73. Now, in his totals Mr. Williams, according to weights, has used 157 observations out of 488 that are now available and have been used by the United States Lake Survey in determining the increment which has been put into this case by Mr. Ray and other engineers of the United States Lake Survey. This increment, as I recollect it, is in the neighborhood of twenty or 21,000.

Now, in the case of the Niagara River, Mr. Williams assumes without any basis of authority in any observation, so far as I am aware, and in contradiction of the observations as indicated themselves, and as finally admitted in the cross-examination by him,—he assumes that the discharge of the Niagara River is dependent on the elevation of Lake Erie at Buffalo for some hours in advance of the measurement of the discharge observation itself.

Mr. Williams, in selecting his groups in the Niagara River

includes the gage elevation, the mean daily gage elevation of the day preceding the observations in his group, preceding the first observation of those in his group. He includes the last day up to midnight, the mean elevation of the last day on which observations are taken in any particular group. Now the effect of this is to put into the elevation which he takes to control or cause the outflow from Lake Erie through the Niagara River, 31 hours in advance of an observation that might begin on eight o'clock in the morning of the first day on which observations were made.

It is a matter of fact, as determined by observations, that the elevation of Lake Erie at Buffalo gage is the cause of the outflow of Lake Erie, with a time lag of 8 to 10 minutes.

Q. At the gaging—

A. At the gaging section, at the Open Section of the Niagara River.

It is a further fact that the time interval for change in conditions of the river between the Buffalo gage and at Chippewa, which is about 20 miles down the river, is approximately 2 hours, and that at the Suspension Bridge gage, which is a couple or three miles further down the river, the time interval is a little over three hours.

Mr. Williams has himself in his testimony accepted his error, as I understand, in this record, and I do not, in the case of the Niagara River, need to dwell on this any further. I do wish to say however that in the case of the Niagara River Mr. Williams has rejected observations and neglected observations, and put them in in a way that is hardly helpful in securing a result in a scientific investigation.

I understand that the direct testimony of both Mr. Freeman and Mr. Stearns, so far as the Niagara River is concerned, depends on Mr. Williams' earlier testimony, in which these rejections, and in which these observations neglected, and in which this improper intrusions of winter observations was contained. Specifically, out of 219 observations available for the International Bridge Section, and in the record in this case at the time Mr. Williams testified, he utilized 30 at the International Bridge Section. Through an oversight, he included some winter observations. These winter observations had the effect of increasing the increment. In the case of the Open Section, Mr. Williams utilized 89 out of 121 observations.

Now, it goes without saying, I think, that if a man is free to accept and reject observations, he can reach almost any

conclusion he may wish. It is a most dangerous thing to put in the hands of an observer, the right or ability to reject observations without ample cause.

In the case of the St. Lawrence River, Mr. Williams in his method of chronological periods and weighting of observations, utilizes the day before the observations began, and does not use the day on which the observations were ended, in deriving the mean elevation of the water surface in the river at Ogdensburg, which determined the flow. Here, in the St. Lawrence, Mr. Williams used the same freedom, a freedom of rejection, and in his selection of quiescent periods included those that are very far from quiescent. The method of deriving an increment in this way has always, as Mr. Williams has used it, gotten a bigger increment than the increments indicated by the exhibits 1, 2, 3 and 4 of the United States in this case.

I want to return to the St. Clair River and its increment, as indicated by Exhibit Number 1, just referred to. In that exhibit, the increment was shown as 23,820. In my direct testimony, I stated that I believed this might be in error as much as 25 per cent., indicating that the increment would lie somewhere between 18,000 and 24,000 roundly. The values of the Lake Survey utilizing the 488 observations in making the determination indicate an increment somewhere in the neighborhood I believe of 21,000, confirming my original view.

The time of travel between the Ogdensburg gage and the gage at the three-point section on the St. Lawrence, was approximately two hours and 40 minutes. The distance is about 16 miles.

Q. Mr. Shenehon, Mr. Williams, also Mr. Stearns and Mr. Freeman checked on some of these increments and reached new and similar opinions in regard to the increments by taking into consideration what we have spoken of as the ratio of fluctuations and the lack of consistency between the rivers in reference to the Government's increments. Will you simply explain just what method was used and with what result?

A. When the mean annual elevations of the lakes Michigan-Huron, Erie and Ontario was plotted, Michigan-Huron with respect to Erie, for instance, the observations aligned themselves to a certain extent, indicating that there is a certain relation in the fluctuations of the two lakes concerned. In the case of Lakes Michigan, Huron and Erie, for instance, as indicated by Shenehon's Exhibit R, Erie appears to fluctuate about 70 per cent. of Michigan-Huron. Now this rela-

tion of lake surfaces, or the adhesion to this relation by the lakes themselves, is not very close for particular years, but taken in five-year means, it shows a very substantial adherence to the ratio indicated.

Now in my earlier testimony, I touched on this same matter and I was asked why Michigan-Huron fluctuated one foot for Erie's fluctuating only .7 of a foot; what was the reason of it, and I answered because it was running that way. What I mean is, what Mr. Williams himself has stated in his testimony, that this is an empirical relation. It is not like the relation of fluctuations which we have on a river like the Niagara, where it is most determinable from day to day, and is a hydraulic relationship. This ratio of fluctuations between great reservoirs like the lakes themselves, is only in part due to the increments of the outflow rivers.

Now, if the St. Clair River and the Niagara River and the St. Lawrence River were free of ice all the year around, we would have in my judgment a very close approximation to a rational relationship between these rivers, when you take into account the change in the supply coming into each reservoir. But we have this condition on the St. Clair River in particular: During the winter season, ice gorges form at times shutting off half the flow of the river. This means that Michigan-Huron must rise because the water is being impounded, and that Lake Erie must fall, because the water impounded in Michigan-Huron is denied to Lake Erie, so during the periods each year, and in certain years during long periods and in large percentages, this abnormal relation exists. It follows then that the relation of fluctuations of Michigan-Huron, Erie must take into account the ice periods, and for that reason the relationship is an empirical one, depending in part on the increments of the rivers, and more particularly that would be during the open season, and then falsified or changed to a certain extent by this condition entering in from the winter flow. This means that Michigan-Huron is always at an artificially high stage and Erie is always at an artificially low stage. Now you may argue by the law of fluctuations from the increment of one river to another, but not with any certainty whatever. And the determination of an increment by this method is crude and inaccurate, in my judgment, compared with the method of deducting the increment from the discharge observations themselves.

The methods used by Mr. Williams and reiterated by Mr. Stearns and Mr. Freeman were to start on the St. Clair with

an inflated increment, in other words an increment derived by methods that in my judgment are inaccurate, and therefore which has been enlarged beyond its proper size; doing the same thing on the St. Lawrence, and by a method of fluctuations determining an increment for the Niagara River. This increment I believe is 34 or 35,000 as finally determined, and shows a line that appears to bear no intimate relation to the discharge observations. After Mr. Williams' conclusion that the Niagara River was really too turbulent to be considered in this case so far as deriving an increment from the discharge observations is concerned, Mr. Williams gives 34,000 or 35,000 as his best judgment as an engineer of the increment of the Niagara River.

Now, Mr. Stearns had a method of deriving an increment also. Mr .Stearns starts with the St. Lawrence and creates by putting in the local supply between the St. Lawrence and the Niagara, he creates the volume of flow in the Niagara River. And in a similar way he deduces from the St. Clair and putting in the intermediate supply, he deduces again the discharge of the Niagara River and with it and these various volumes of flow as indicated by his mean determinations, he derives an increment in that way. I believe on the face of it, this method of derivation is so uncertain, or in other words it is so certain to give erroneous results, that it needs little comment. When I come to the matter of discussing the supply, the runoff and so on as determined by Mr. Stearns and Mr. Williams, I think it will become very apparent that the actual amount of the runoff, the local supply of any one of these lakes is a quantity that is too indeterminate and has such different dimensions when gotten out by the different witnesses for the Sanitary District, and I may include in that Mr. Thomas Russell of the Lake Survey itself, that it is not safe to determine the trend of a line that really requires very accurate measurements by any such inaccurate method.

Mr. Adcock: What do you mean by that?

A. You read your own testimony and you will strike that. It has certainly been referred to by your own witnesses, both Williams and Stearns, and Freeman.

Q. You said "including Thomas Russell of the Lake Survey."

A. Yes, sir.

Mr. Williams: If you would include the report of Thomas Russell, I think you would be all right.

Mr. Hopkins: As referred to in this testimony?

The Witness: As referred to in this testimony, and as indicated by his report of 1904, already referred to in this case.

Mr. Austrian: Q. That is he is in the same position as the others. I understand his conclusions—

The Witness: I will discuss that a little later.

Mr. Austrian: I would like to get something—

Mr. Adcock: Q. You are referring to the report of Thomas Russell of 1904, are you not?

A. Yes.

Q. That has been referred to in evidence?

A. Yes, I so stated, Mr. Adcock.

Q. You said including Thomas Russell. I did not know whether you referred just to the report, or something else he might have said.

A. I did correct that.

Mr. Hopkins: Q. Mr. Shenehon, how did the witnesses for the defendant determine their increment, using the ratio of fluctuations; what stream did they begin with and just how did they reach their conclusions, in a very general way?

A. The Niagara River increment as determined by the ratio of fluctuations began, started with the inflated increment of the St. Clair, and producing an increment by the ratio of fluctuations, and the change in supply between the two rivers, utilizing Mr. Williams' ratios, I believe, of fluctuations; and then starting on the St. Lawrence with an inflated increment and proceeding by the law of fluctuations with the change in supply between the St. Lawrence and the Niagara.

Q. Have you determined an increment by the same or a similar method, beginning with the Niagara River increment as determined by the Lake Survey? If so, what result did you get?

A. Yes, I started with the increment of the Niagara River of 21,900. I believe in this discussion I called it even 22,000; and proceeding by the same methods as used by Mr. Williams, I derive for the St. Clair an increment of 14,600, and in doing this I use the ratios indicated on Shenehon's Exhibit R; that is the relation between the Michigan-Huron, Erie as 70 per cent. and between Erie and Ontario, 135 per cent.

For the St. Lawrence, I derive by this method an increment of 18,800. Now, for reasons already stated, I have shown that this method of deriving an increment is an approximation only and is subject to the error in the co-efficient or ratio

utilized. This is not the true hydraulic ratio, but is an empirical ratio which involves ice effect, local supply, run-off, rainfall and so on and is a rather crude approximation.

There is a reason however that the all the year around increment of the St. Clair River is smaller than the increment derived during the open season because the ice conditions are likely to cause a lower increment during the ice period, so that the all the year around increment must be taken in connection with the ice period, as well. The increment for the whole year is a thing that would determine the lowering due to such a diversion as that at Chicago.

In the case of the St. Clair River, we have extreme ice conditions, as indicated by our records of rivers in the Lake Survey, and in the case of Lake Ontario the ice conditions are less pronounced, so far as the retardation of flow from Lake Ontario is concerned.

Here again on the St. Lawrence, however, there is the chance or probability that the winter increment is a little less than the summer increment and that the all the year around increment is less than the values given by the discharge observations and the loss of level for both Ontario and Erie is likely to be somewhat in excess of the values derived from open season increments.

Now it appears to me the most reasonable method of procedure to start on the river that is midway of the series, the series being St. Clair, Niagara and St. Lawrence, and derive the increments for the other two rivers. It appears to me reasonable also and proper, because the increment, in my judgment, of the Niagara River is the best established of the increments of the three rivers concerned.

Q. Why is that so?

A. I stated this in my earlier evidence in 1909. I stated that in my judgment the increment of the Niagara River was known within 5 per cent.; the increment of the St. Lawrence, within 10 per cent., and the chart, U. S. Exhibit number 1, showed an increment for the St. Clair that might be in error 25 per cent. The increment for the Niagara River covers a range of lake stage of nearly four feet, 3.92 at the International Bridge. It is a case where we have the increment of the river corroborated, the increment of the river at the International Bridge Section corroborated by the increment of the river at the Open Section. These are very definitely indicated by Shenehon's Exhibits B and D.

The increment is further corroborated by the derivations

taken out for the Gorge Pool and Whirlpool as shown by Shenehon's Exhibits E, F, G and H.

Q. How about the number of measurements in the Niagara River, number of observations?

A. There are 340 observations, for discharge, utilized in Exhibits B and D, already referred to.

Q. Is there any backwater effect in the Niagara River?

A. No, the conditions hydraulically are the simplest of any of the rivers considered. The increment of the St. Clair on the other hand is the most complex problem, so far as the derivation of an increment is concerned that we have in this case, and Mr. Gardner S. Williams so states in his testimony. I think I am correct in that. I can refer to his words if you wish.

The backwater effect from Lake St. Clair has made the problem an exceedingly difficult one, and it was for that reason that I indicated in my earlier testimony my judgment that the increment might be 25 per cent. in error.

We have at the present time, however, 488 observations on the St. Clair and we are getting closer to the increment certainly, and as I before stated it is in the neighborhood of 20,000 or 21,000. But we have always had, as indicated by the various reports, on the St. Clair a big range in our increment. It has ranged anywhere from 16,000 up to 24,000, and Mr. Williams runs it up to 29,000, so the thing is very indeterminate. Perhaps I should exclude Mr. Williams determinations in this case.

In the case of the St. Lawrence, we have not a very good range of Lake stage during the observations; just two groups of observations, with 93 discharge observations; range of a little over two feet, extreme range. The proper method of procedure, therefore, in my judgment, is to begin on the Niagara River and by the method of fluctuations proceed to the increments of these two rivers in which the increments are less well known.

Q. How many of the observations on the Niagara River were made by you and how many by other men in the Lake Survey Office?

A. I myself, personally, handled the instruments on a very small percentage of the observations, probably less than 10 per cent. The observations, however, were made under my direction and under my planning, in conjunction with Mr. Haskell, as principal assistant engineer of the Lake Survey. We utilized, however, 19 observations, I believe, which were

made by the Board of Engineers on Deep Waterways, by Mr. C. B. Stewart. While I was in charge of the Buffalo office at that time, I did not interfere in any way with the measurement of the volume of flow. Mr. Stewart had been working on that in conjunction with Mr. Haskell, and he proceeded under the methods in use at the time that I reached Buffalo. That was a period of two months that I was there.

Q. Did you hear the testimony in this case of Mr. Richmond, Junior Engineer, United States Lake Survey Office?

A. Yes, sir.

Q. Are you familiar with the section which he measured, he testified he measured?

A. Yes.

Q. Known as the Split Section?

A. Yes, I have visited the section, or the two sections on either side of Grand Island.

Q. What are the general conditions there as to turbulence, and as to being proper sections for discharge measurements and so on?

A. I regard the sections as excellent ones, speaking of the two individual channels. The current velocity is lower than I myself prefer to select for a discharge section, but for the corroboration or the check on the sections further up the river, this is a most valuable deviation from the rule that I myself have made in selecting more rapid currents. It gives a bigger variety in the sections measured. There was no indication whatever of any turbulence in the water.

The whole reach of the river from the head of Grand Island, or even further up, from a little below the International Bridge, the whole reach of the river is reasonably placid. Perhaps I might make that from the foot of Squaw Island to the vicinity of Niagara Falls, the river is running placid and serene; and during the summer season it is a place where a large number of pleasure craft of all kinds are in operation, launches, row boats. It is one of the play grounds or play rivers of the people of Buffalo. I regard it as an excellent selection of a section. And as I say, I visited the section and observed the condition of the river, and the flow at that point, or those two points.

Q. You referred to the difficulties in determining the run-off in making up the local supply, say of Lakes Erie and Ontario. There have been three different computations introduced in evidence as to this run-off, or referred to, one by Mr. Williams, one by Mr. Stearns and one that of Mr. Rus-

sell in the Lake Survey, referred to. Will you just tell what those various methods were, beginning with Mr. Russell's, and the relative values of the methods or results obtained by each.

A. The method of reaching a generalization as to the run-off used by Mr. Russell was to assume that the yield or contribution of the Lake Erie basin, including the land area and the lake itself, was in the same proportion to the supply or yield of the basins of Lake Superior and Michigan-Huron.

Under this assumption the Lake Erie basin should contribute 30,100 cubic seconds feet.

Using this generalization the yield per square mile of territory is the only consideration. It ignores in every way the topographical conditions, and the geological conditions, the conditions as to forestation or cultivation, and simply makes this broad generalization. Of course this is not a determinate method of arriving at the solution of this very important factor in the case.

Mr. Russell in other places in his report of 1904 speaks of the run-off as six-tenths of the rainfall. As the rainfall is about 34 inches for the year this would give a run-off approximating for the year 45,000 cubic seconds feet.

Q. Does he in determining the run-off take into consideration rainfall or evaporation, at all?

A. No, not in that generalization. He treats the evaporation from the lake surface as a separate affair.

Q. And in trying to determine the run-off of one part of that big drainage area of the Great Lakes, as against another part, is there any value in the method used?

A. As indicated by the conclusions of Mr. Gardner S. Williams in this case, which I regard as the only professional conclusion reached in the matter of run-off in this case, Mr. Russell is widely in error.

Q. Now what is Mr. Stearns' method of determining the run-off?

A. Mr. Stearns' method, as I understand it, was to work out a formula from certain drainage basins in New York State, Massachusetts and Pennsylvania, and then proceed to apply this formula to the drainage basins of the Great Lakes. I think it is generally conceded that run-off is a very complex thing. Mr. Stearns, as I understand it, did not give any large considerations, or give any consideration to the topographical or geological conditions of the two drainage basins concerned. And Mr. Stearns' values may be regarded

as estimates reached by a formula derived on water sheds that are not comparable, in my judgment, to those of Lake Erie and Lake Ontario.

Q. What was Mr. Williams' method?

A. Mr. Williams examined such data as was available of the stream flow, the streams entering Lake Erie and entering Lake Ontario. In the case of Lake Erie, he examined the flow for a period of years of streams in Lake Erie, amounting to about 33 per cent. as I recollect it of the run-off basin; and in the case of Ontario, 37 per cent.

Now we have not, so far as I am aware, in any engineering literature, any statement of the run-off that has the professional scientific basis that the conclusions reached by Mr. Williams have. It is a contribution to our knowlege of the Great Lakes.

Q. Now taking the values given by Mr. Williams for the run-off, and taking the evaporation and rainfall as given by either Mr. Williams or Mr. Stearns, what is the consistency between the rivers, as measured by the United States Engineers?

A. I would like to state first certain conclusions, as I understand them, derived by these three men mentioned. As I understand it, Mr. Thomas Russell makes the summer run-off of Lake Erie about 45,000 cubic seconds feet. During the months, June to November, inclusive, Mr. Gardner S. Williams makes the run-off 7,640. During the same months, June to November, Mr. Stearns mades the run-off for Lake Erie 16,230. Mr. Stearns' figures are more than twice those of Mr. Williams, and Mr. Russell's are somewhat in excess of the figures of either of them. I am not certain that Mr. Russell's figures are not for the full year.

In the case of Lake Ontario, Mr. Gardner S. Williams' figures are 23,800 cubic feet per second and Mr. Stearns' figures 15,260.

Now, I don't know what Mr. Russell's are for Lake Ontario. I have not looked them up. Having in mind these values—

Q. Did Mr. Russell make any observations whatever in regard to these determinations?

A. I understand Mr. Russell's generalization is a matter of judgment taking .6 of rainfall for year, somewhat less for summer.

With these wide variations in the generalization of Mr. Russell, the estimate of Mr. Stearns and the determination of

Mr. Williams, the danger of attempting to produce an increment for the Niagara River by starting at the St. Lawrence or starting at the St. Clair, to my mind becomes very evident.

While on this matter, I want to take up another thing where Mr. Russell has been quoted in this case; his 1904 report has been quoted by Mr. Williams. That is his reference to 81 inches of evaporation on the surface of Lake Erie. This 87 inches, as I understand it, is a deduction from the guess as to the run-off of the Lake Erie basin, and Mr. Williams in particular, with his knowledge of the run-off, might be regarded as unjustified in referring to this conclusion reached by Mr. Russell in this case, in that report referred to.

Now, I myself, have made a determination or computation with a view of investigating the question of whether or not these three rivers, the St. Clair, the Niagara and the St. Lawrence, are consistent and in accord. That is if you start with the St. Clair and put in the local supply and reach the Niagara, whether or not you reach a value that is consistent with the observed value. And then proceeding on down to the St. Lawrence, or starting at the St. Lawrence and coming back to the Niagara, you get consistent results.

In this determination, we have certain things that have been subject to criticism, but I am willing to pass those by because none of us has any very accurate knowledge as to the evaporation of the lake surfaces. We have no very valuable information as to the rainfall on the Great Lakes, and when I say this, I mean as to the absolute quantities. We may know the relative values of these things tolerably close, but as to the absolute quantities we haven't any very definite information. So, I am willing to accept the values put into this case by Mr. Stearns in his Exhibit Number 1, as being sufficient for the purposes in hand. I refer to the lake surfaces in mentioning evaporation and rainfall.

Now, starting with the St. Clair River, using the Lake Survey equation as indicated in the report of 1912, which I regard as the best value we have for the volume of flow for the St. Clair River, and confining this investigation to the months of June to November, inclusive, used by Mr. Stearns in his Exhibit 1, and taking a series of years beginning in 1891 and ending in 1906—I take that series for three reasons: One is that it is alleged in this case that there was a change of regimen in the St. Clair River about 1889-'90, so I begin with the year 1891, and I terminate with the year 1906,

because that is as far as Mr. Stearns carried it, and I wish to use his values as derived in his Exhibit 1. That is one reason. The other reason is because the years are fairly symmetrical, around the earlier discharge observations, at least. And another reason is because we have a more definite knowledge in these later years both of rainfall and elevations of lake surfaces than we had in the earlier years. The local supply and storage which is indicated on Table B, column 6, of Mr. Stearns' report I change only by substituting Mr. Williams' value for the run-off, 7,640, instead of the mean value, 16,230, used by Mr. Stearns. The local supply, as I make it, is 15,100, that is, local supply and storage. I accept Mr. Stearns' figures for the storage because I checked him and know that his figures are accurate. That is an easily determinable thing. The deduced value by adding the local supply and storage to the volume of flow of the St. Clair River is 211,100 for the flow of the Niagara River. The flow as indicated by the equation of the Lake Survey, Government's Exhibit Number 3 in this case, is 206,500. This shows an accord, an agreement between the flow of the St. Clair River and the Niagara River of 4,600 feet, which is about 2 per cent. The value derived from the observations of discharge on the Niagara is 4,600 smaller than the deduced value by adding the intermediate supply and storage.

Now, starting on the St. Lawrence River and coming to the Niagara River, I refer to Shenehon's Exhibit T. This is self-explanatory, I believe. It takes the value of the St. Lawrence River from the Lake Survey report of 1912, and takes the same value for the Niagara River as computed from the discharges as just indicated as coming from Exhibit 3, U. S. Exhibit 3.

The conclusion appearing from this sheet is that the St. Lawrence checks the Niagara within 4,600 feet; and in this case the actual value of the discharge derived from the discharge observations is 4,600 feet less than the value derived by interpolating or deducting the intermediate supply of Lake Ontario.

I wish to state in this Exhibit T, the run-off for Lake Ontario is taken from Mr. Stearns' Exhibit Number 1. Now, as I believe that Mr. Williams' values for the run-off are much to be preferred over those of Mr. Stearns, which are more or less estimates, I have proceeded to make an analysis starting with the St. Lawrence, using the same value for the mean flow of the 16 years as used in Exhibit T, using the same local

supply and storage as determined by Mr. Stearns except that the run-off is taken from the values given by Mr. Gardner S. Williams in his Table 59A, Exhibit 34.

This shows that the Niagara River as deduced by subtracting from the St. Lawrence the intermediate supply and storage, checks the volume of flow indicated by the discharge observations within 4,000 cubic seconds feet; and this indicates that the value of the flow derived from the discharge measurements is 4,000 feet too large as compared with the St. Lawrence.

Now, it should be noted that in the analysis, utilizing Mr. Stearns' run-off, the check is within about 2 per cent., but on the other side, Niagara being indicated as too small, while using Mr. Williams' figures for the run-off, the Niagara is indicated as about 2 per cent. too large.

That is the value of the flow shown by the discharge observations is too large. As an inference or corollary from these statements, if we use Mr. Gardner S. Williams' figures, the St. Clair and the St. Lawrence River checked each other within about three to four per cent. indicating for the whole series an excellent corroboration.

Recess to 2 P. M.

After Recess 2 P. M.

FRANCIS C. SHENEHON, resumed the stand and further testified as follows:

Mr. Hopkins: Q. Mr. Williams in his testimony gave some opinions in regard to the consistency or lack of consistency of rivers, using those elements of local supply you were speaking of this morning. Just what was his method and wherein is it fallacious, if at all?

A. As I understand the analysis made by Mr. Williams to determine the consistency or the converse of the three rivers, St. Clair, Niagara and St. Lawrence, Mr. Williams chose the years 1900 to 1904, inclusive, and proceeded to write out the volume of flow from the St. Clair River without taking into consideration or including the retardation of the ice period.

Mr. Williams then introduces the intermediate supply much as in the case indicated by my testimony this morning in

the physical analysis, except that he uses the full year, that is, taking the run-off from the Erie Basin, taking the rainfall on the lake surface and the evaporation from the lake surface; then the volume of flow of the Niagara River, giving no correction for any possible small ice conditions that might prevail.

He then takes the local supply of Lake Ontario including the run-off, the rainfall on the lake surface, the evaporation from the lake surface and finally the volume of flow of the St. Lawrence River during the full year, without making any deductions, as I understand, for the retardation by ice coming in the winter months.

Now, in my judgment it is an erroneous method in the fact that Mr. Williams did not make any correction for the flow of the St. Clair River by reason of the ice periods. The particular years used by Mr. Williams include the years 1900, 1901, 1902, in which years Mr. Louis G. Sabin made observations and deductions as to the ice effect.

Sabin's report on this subject is shown on page 2837 of the Lake Survey Report of 1902. As an inference from the retardation shown in the years 1900 to February 1902, inclusive, it appears that the mean retardation due to ice spread over the full 12 months of the year for the three years concerned averages 14,200 cubic seconds feet. Should this average be present also in the years 1903 and 1904, it would seem to me that Mr. Williams should make a correction, in other words, cut down the volume of flow of the St. Clair as indicated in his statement by from 12 to 14,000 cubic seconds feet.

Now, I believe it to be a matter of fact that the retardation of the Niagara River by reason of ice is exceedingly small. That is, the retardation of the outflow. The ice troubles in the Niagara River are those in the vicinity of the Falls. The power companies sometimes have considerable difficulties with ice, but the ice is of a kind that has very little effect on retarding the outflow of the Niagara River; the position of the ice in the lower river at Chippewa, has a very small effect.

The ice effect in the St. Lawrence River is known to have some considerable dimension. That is discussed in my own report of 1902, where the methods used are not entirely conclusive, but it has some considerable value I think in showing the retardation from ice in that river, but the principal case where ice is a big factor so far as the retardation of the outflow is concerned is in the St. Clair River.

I believe also Mr. Williams neglected the change in outflow in the St. Lawrence due to the building of the Gut Dam in 1903. That, however, would involve only the year 1904, and part of the year 1903, and the error entering on that account would be not large.

I believe Mr. Williams also neglected the change of storage, but the error coming from that I think would be small. I am not certain as to that change of storage. It is immaterial; the change of storage would probably be very small.

Q. I call your attention to plate 10 of Williams' Exhibit 34, which purports to show dredging in the St. Clair River, Lake St. Clair and Detroit River; and call your attention to the two large white portions which are supposed to indicate the amount of dredging. I wish you would tell just where those are, and what effect, if any, that dredging would have upon the outflow from Huron to Lake Erie.

A. This plate 10 is misleading, as all profiles are likely to be where a large distance is squeezed up, relatively, and elevations are shown on a large scale. Glancing at this chart casually, I should be inclined to think that some very important dams have been removed at the head of the St. Clair River, at the foot of the St. Clair River, at the head of the Detroit River and in the lower reaches of the Detroit River.

Q. Just where were those removals? Take first the one shown above Fort Gratiot?

A. Now, what appears on this profile, or what looks to me like a dam with two points on it, two crests at the lefthand side, is the dredging done on what is known as the middle ground which is about a mile and a half out in Lake Huron. As I recollect it, the dredged cut there is about a thousand feet wide and the material was dumped alongside, so that any material taken away is redeposited in their regular dumps alongside. But the lake there—I am stating this somewhat at random, but it is my belief—at right angles to the sailing course is two to three miles wide. I believe therefore that the removal of this material could have had no influence whatever on the outflow conditions of the St. Clair River.

Now, the dam, or what appears on this plate to me to be a dam at the foot of the St. Clair River, is in part across the bar at the Delta of the St. Clair River, extending in a straight line the south channel.

Now, as a matter of fact this has removed some material, most of it being in the lake itself, and I am not sure that it is not practically all of it in Lake St. Clair where there is

such a considerable width that the effect on the volume of flow is very inconsiderable.

The amount of water that flows through this particular channel, in acordance with the report of Mr. Richmond in this case is about 30 per cent. of the volume of flow of the river at that point. The other chanels, so far as I am aware, are in their natural condition, including the old meandering course of the south channel. As a matter of fact, I believe 12-foot navigation did pass through the south channel prior to this excavation in the early days, possibly with some little excavation. I should wish to refer to the chart to verify that statement, but in the meandering course of the old south channel, which is not before me as I testify, there is a considerable depth, and when I say considerable depth, I refer to nine to twelve feet, with a possible correction on looking at the chart.

I believe that the outflow of the St. Clair River is not appreciably assisted by the removal of this material at the head of Lake St. Clair; and a similar statement should be made regarding the removal of the third dam of this series, which appears at the foot of Lake St. Clair, at the head of the Detroit River. This appears to be about two miles above the Windmill Point Lighthouse, which is the real head of the river, and therefore in Lake St. Clair material, as I recollect it was dumped alongside and had a retarding influeence that would probably take care of any little lowering effect that might come from the excavation.

The little peaks shown in the lower Detroit River appear to be from less than 1 foot to about 3 feet in depth of excavation. While the removal of these, unless compensation was complete at that point—and I understand there was some material dumped in the river that must have had some conserving effect—must have had a very small influence, as it appears to me on the elevation of Lake St. Clair, and with the small influence on Lake St. Clair, the effect of Michigan-Huron as to lowering must have been very small indeed, so far as plate 10 indicates this.

Q. I call your attention to Table 40 of Williams' Exhibit 34, and will ask you whether or not Mr. Williams took into consideration ice effect in getting those results?

A. This Table Number 40 appears to be a statement of the volume of flow of the St. Clair River by the defendant's equation by months for the years 1900 to 1907, inclusive. It appears to me that the values for the discharge, aside from

the erroneous equation used are in error further by the fact that no consideration is taken of the retarding influence of the ice, which has previously been discussed. The volume of flow for January, February and March appear to depend on the elevations of the lake surfaces, Lake Huron and St. Clair, flowing just as if the stream were entirely unimpeded, as it flows in the month of July, for instance.

Q. Mr. Shenehon, what is your opinion as to the accuracy with which large rivers can be measured, as compared with measuring small streams?

A. I should not attempt to measure a small stream; and by that I mean a stream with a volume of flow of perhaps 500 cubic seconds feet or less, with current meters of the types used in the river gaging of the Lake Survey on the rivers of the Great Lakes. I refer to types A and B. I would not expect to get a precision much better than 5 per cent.

Mr. Adcock: That is A and B of the Haskell meter?

A. Yes, the large meter I am speaking of now.

Mr. Hopkins: Q. Why not?

A. The meter seems out of proportion to the size of the channel that I have in mind. I am thinking now of the canal at Cornell, and with a depth of perhaps three and a half feet. I do not see myself how any vertical curves can be determined in a canal of that kind or in a stream of that depth with a meter of that size, that would mean anything in the final precision of the work better than five per cent. If the observer should from some other experience set down that the ratio of velocities in the vertical to the mean velocity or to some velocity measured might be 90 per cent., that might help matters.

I think I can illustrate this in this way: The wheel 7 inches in diameter in a stream of say 3½ feet in depth would correspond to a wheel of a diameter of 10 times 7 inches, 70 inches, or about 6 feet, in a stream 35 feet deep.

Mr. Adcock: Q. That is it occupies too much of the cross sectional area?

A. It occupies too much of the cross sectional area and prevents your getting the trend of the vertical curve close to the bottom or the transverse curve close to the side of your canal, in the case of the canal, so the objection on my part is that there is a lack of proportion between the size of the meter and the canal that would prevent any work of a finer precision than five per cent.

I think what appears to be good practice in the measure-

ment of small streams, to take a meter, current meter on a rod and wade out in the stream indicates that the observer does not expect a precision much better than 5 or 10 per cent., because the observer himself walking into the stream is distorting the currents; that is, he is forming what corresponds to a bridge pier, and it is a movable pier, a pier that is one place at one time, and is taken out. What the original condition of the stream flow was without the observer's interference is not determined, I should judge, by gagings of that kind.

Q. With what degree of accuracy do you think large rivers can be measured, rivers like the Niagara, St. Clair and St. Lawrence?

A. In my judgment, we have determined the volume of outflow at mean stage of the observations within 1 per cent. on the St. Clair and the Niagara Rivers, and possibly with a little less precision on the St. Lawrence River.

Q. There has been a great deal said in this record about the violence of Lake Erie changes at Buffalo. Just what changes do take place there in the elevation, and how long do they last and what are they?

A. (No response.)

Mr. Austrian: Mr. Shenehon, I would like to have you tell us with what precision in your opinion you could measure small streams, such as the Chicago Sanitary District Canal, the Illinois River, the Chicago River?

A. Well, I am not familiar with the conditions of the Illinois River. I should say a canal like the Drainage Canal could be measured with a precision better than 2 per cent. And I have in mind water power canals at Niagara Falls where the water used by the power companies is determined by the United States Lake Survey, and my belief is that the precision with which the flow is measured there is about 2 per cent. or a little better.

I may say that in my practice in the gaging of streams on the Great Lakes, we did not attempt to measure with current meters the volume of flow in the end areas, back of the terminal cribs on the Niagara or the St. Lawrence, believing that we could in those little areas get better results and sufficiently good results by running a line of floats down.

Q. (Last question by Mr. Hopkins read.)

A. I refer, in answering this question, to Shenehon's Exhibits K, L, M, and N, which is known in this case as the three curve series. During the observations of 1900, 1907

and 1908, of the Niagara River, it is rarely that the fluctuation, or rise or fall, of Lake Erie exceeds two inches in an hour, or one-half inch in 15 minutes. The gradual rise as it comes in the majority of cases during the discharge observations, or the corresponding fall of the lake is so almost imperceptible that it may not be regarded as violent fluctuations.

Of course there are cases where the fluctuation per hour is somewhat greater than I have stated, but there are so many observations during the periods when the fluctuations are at the lesser rate, or even below that, that we do not need to consider as a cause of inaccuracy in the Niagara River work, as opposed to the accuracy of the other two rivers, this matter of lake fluctuations.

Q. How do the observations when the level is changing rapidly compare with the observations when the level is changing more slowly?

A. With the rising stage, there is an increased flow of perhaps 1 per cent.; with a falling stage, a decreased flow of perhaps the same amount, and in the end the effect of the fluctuation is balanced in a series of observations. The final inaccuracy in the result and in the increment is exceedingly small.

Q. There has also been a great deal said about the turbulence of the Niagara River and the difficulty of measuring the discharge of that river. What is your opinion as to that?

A. The difficulty of measuring the discharge of the Niagara River, the physical difficulties were somewhat greater than the ordinary river that an engineer is called upon to measure the volume of flow; these are the depth of the stream, the velocity of the current. But in the end, the sections above the International Bridge, and the Open Section and the Third Section have permitted measurements of the highest precision, as I view it.

The facts as regards the International Bridge Section have all been stated by me, and I concluded, after an investigation of the error due to the eddies around the bridge piers, that one-half of 1 per cent. would in all probability measure that.

As regards the Open Section, I have made an investigation on the assumption that there may be some perturbation of the water close to the bottom. I assumed for the purpose of this computation—not as a matter of fact, but for the purposes of this computation,—that the perturbation for the

bottom 20 per cent. of the cross sectional area, bottom 20 per cent. in depth of the cross sectional area was what Mr. Groat in his paper refers to as violent boilers; and I assumed that his mean value of the under registration of the Haskell Current Meter of 3 to 4 per cent.—I took 3 1/2 per cent. as an average, and applying that even though there were an under registration of 3 1/2 per cent. in this whole area, the final effect on the volume of flow would only be 1/2 of 1 per cent., and if the conclusions of Mr. Groat are correct, would make a lesser value by 1/2 of 1 per cent. due to that cause.

While I am touching on this, I would like to state one other thing that has been brought into this case; that is the matter of the direction of flow. If the very small correction for what is known as the direction of the flow, that is the water not passing through the cross section at right angles with the section, if that has not taken into account all the deviations from the right line, then any error coming from this omission would be that we have measured the flow too great; in other words the current meter measures the volume of the flow, and the direction correction is to make it smaller. In other words this too great volume of flow indicated by an erroneous or too small direction correction tends to compensate and offset any error coming from under registration.

Q. One of the criticisms made of the work of the Lake Survey at the Niagara River has been concerning the difficulty of relating the discharge to the stage of Lake Erie. What have you to say as to that?

A. I had intended to speak, in answering the question regarding the perturbation, of what knowledge we have as to whether there is perturbation in the lower stratum of the water; and I have made a very complete study of the vertical curves, that is the relation of the velocities beginning at the surface down to the bottom in the various streams considered in this case; the St. Clair River as gaged by Mr. Sabin at the Dry Dock Section, the Niagara River in the Open Section, the Niagara River at the Bridge Section, the St. Lawrence River at the Three Point Section and the vertical curves observed by Mr. Richmond in what is known as the Split Section of the Niagara River.

In these examinations for the St. Clair River and for the Open Section and Split Section of the Niagara and the Three Point Section of the St. Lawrence, I took the ten stations

which appeared to have the bulk of the flow, or more than 50 per cent. of the flow in each case and combined them into a single vertical curve, and superimposed these composite curves one on another. These curves were on a percentage basis of depth and velocity, and the curve of the Open Section of the Niagara River so closely overlaps and covers the curve of the St. Lawrence that they are scarcely distinguishable from each other. The curve of the St. Clair River shows towards the bottom a somewhat higher velocity, indicating a smoother bottom. The third section almost exactly duplicates the Open Section of the Niagara, and the St. Lawrence curves, except that where the composite curve the line strikes bottom, there is a little less velocity. These as a series indicate that one section as compared with another is not largely influenced by perturbation; that if there is any perturbation, it is common to the whole group.

Q. (Last question read.)

A. This matter was investigated by me, and the conclusions reached are shown by means of Shenehon's Exhibits E, F, G and H. In this series, the volume of flow is related to sheltered gages in the river, instead of relating it directly to the Buffalo gage. The relations between the fluctuations of the particular river point chosen, the elevation of water surface in the gorge, and Suspension Bridge and the elevation of the Whirlpool are referred by water levels transfers to the Cleveland gage and to the Buffalo gage both on Lake Erie.

I find that in the case of the use of the Cleveland gage and the ratio of fluctuations established between that by monthly mean water surface elevations and the water at the Suspension Bridge and the water in the Whirlpool that the increment derived by the direct reference to the Buffalo gage is almost exactly reproduced. In other words, the increments derived are all in the vicinity of 22,000. This to my mind is a complete verification of the work of directly relating the volume of flow to Lake Erie level at Buffalo. I believe the demonstration is most complete.

I may add that the observations used in this work are those of 1907-1908, because we did not have these lower river gages for the earlier work. These charts I believe are self explanatory, and the method employed in reaching these conclusions I believe to be a correct one.

Q. You made certain meter tests by comparing the registration of the meter with colored water, and testified in regard to that in the original testimony?

A. Yes.

Q. What is your opinion as to the accuracy of that test, having in mind that the colored water is near the top, as to whether that gives any indication of the waters below the surface.

A. Well, in connection with what I have said about the precision with which the composite vertical curves in one river will reproduce those in another, I believe that the velocity indications of the current meter, with ratings on a still water base, are applicable for other depths than the surface depths. I believe no error of any magnitude has entered into this work for the reason that the current velocity indicated in the river is rendered incorrect by a still water rating of the instrument used for measuring the velocity of flow.

Q. Mr. Shenehon, did you and the engineers in the Lake Survey take into consideration the back water effect of Lake St. Clair, in determining the increment of the St. Clair River?

A. That is in U. S. Exhibit Number 1, as originally put in this case.

Q. And in all your determinations, that was considered, was it?

A. In the recent Lake Survey determinations, and by that I refer to the report of the Lake Survey, 1912, this has been very fully considered, in the reduction of 488 observations.

Mr. Adcock: Was it considered before that?

A. In connection with the U. S. Exhibit Number 1, the period covered by the observations was taken as being sufficiently long so that Lake St. Clair would maintain its proper relative position with respect to Lake Huron. I have investigated the fact as to whether or not this is true for the years 1898 to 1908, inclusive, excluding 1901, and I find that they were nearly in accord with the relation shown by the Lake Survey and indicated on an exhibit in this case. I take my evidence from Williams' Exhibit Number 34, where he has made a reduction covering this point. The exhibit referred to is Shenehon's Exhibit R.

I might refer, as I mentioned Mr. Williams' Exhibit 34, to table 16. At the bottom of the table, the values given are for the weighted Huron and Erie elevations, 580.608, and for Lake Erie, 572.115. I have taken off values from this curve and I find that the relation that should exist between Michigan-Huron and Lake St. Clair, in accordance with the law expressed on Shenehon's Exhibit R, would indicate 580.61 for Michigan-Huron, and 572.11 for Lake St.

Clair. It may be objected that this contains the year 1908, but the year 1908 was plotted on the curve in Exhibit Number 1, and appeared to be in general consonance with the other observations. Lake St. Clair appears to have been about 0.06 low by Mr. Williams' table VII.

Q. Wasn't that one of the reasons assigned by Mr. Freeman for the rejection of the Lake Survey's increment

A. Mr. Freeman's reasons, as I recollect them, for rejecting the—giving more weight to the increments as derived by Mr. Williams than to those of the Lake Survey, as indicated by the direct testimony, was that I think he spoke of: Shenehon did not take into account the elevation of Lake St. Clair. Another reason was that: Shenehon did not use the three point method. Another was, that volumes of flow of the St. Clair River and the Niagara River did not check up, when you pass by interpolating intermediate supply from one to the other.

In the end, as regards the Niagara River, he regarded the perturbations or turbulence of the river as a factor to be considered. In his early statement he did not have in mind the third section, because it had not yet been measured at that time.

I wish to make a statement regarding Mr. Freeman's testimony on turbulence, and the nature of the bottom of the Niagara River. Mr. Freeman was employed, as I understand it, by the Ontario Power Company of Niagara Falls, Ontario, and had to do with the un-watering, or at least viewed the space unwatered by their divertors in the rapids. Now the rapids just above the cataract at Niagara Falls make a descent of about 60 feet in something like 3/4 of a mile. The Ontario Company's intake, where the bottom was unwatered, in order to put in the permanent diverting weir, was one of the most ragged pieces of bottom one could expect to find, with the great descent—I think the water descends about 20 feet in that distance, under the earlier condition—and the great rapidity of the water, the cascades entering there, the bottom was doubtless cut up with pot holes in the solid rock, and it is a position where ice carrying boulders would drop the boulders, the ice being broken up by its descent over the first cascade, so there is no comparison whatever, so far as I am aware, of the nature of the bottom there and the Niagara River from Chippewa up to the head of the river itself at Lake Erie.

I wish to speak of one other thing regarding the head of the river. The first descent of five feet from Lake Erie down

to the vicinity say of the Open Section, in the upper reach of this, the water is traveling at a fairly high velocity but there is no rapids there, there is no breaking water. On a still day, this flow of the water is perfectly smooth. There are no white horses, no riffles indicating a rapids, anything of that kind.

I am very familiar with that river because I maintained water gages there getting the slope of the river under the Board of Engineers on Deep Waterways, and for two months made almost tri-weekly inspection of these gages, and testify regarding this with very intimate knowledge of the actual conditions.

Q. What is your present opinion as to the increment of the St. Clair River, what it is, and its accuracy in the light of all this study that you have made, the testimony that you have read, the recent measurements and observations of the Lake Survey?

A. I believe the increment of the St. Clair River is in the neighborhood of 21,000 cubic seconds feet, and the precision is probably within 10 to 15 per cent. In making this statement, I may wish to qualify this by reference to a Lake Survey document, which is not here at the present time. I am basing this on my recollection of certain increments gotten out separately from the Gorge Section and the Dry Dock Section at different times.

Q. The same question as to the Niagara River?

A. 21,900, with a precision of five per cent.

Q. The same question as to the St. Lawrence River?

A. 22,000 approximately, with a precision possibly of 20 per cent.

Q. Why do you give the precision of the Niagara greater than the St. Clair?

A. There are two reasons why I give the precision of the Niagara higher than the St. Clair. One is the fact that in the Niagara we have approximately 4 feet of range in our discharge observations, 4 feet in the range of the elevations of Lake Erie, from elevation 570 to 573.92, more accurately. This long range of our observations gives a more accurate trend of the curve. In other words the precision of the observations, other things being equal, is proportional to the range of lake stage which is secured from the discharge observations.

Another reason why I count the increment of the Niagara River as of high precision is the fact that the Open Section increment checks so very closely the increment of the

Bridge Section. The increment derived entirely independently on the Open Section is 21,640. That of the Bridge Section 21,900. Then on the Niagara, we have the opportunity of checking the increment by referring it to other gages as at the Suspension Bridge and in the Whirlpool, and I may add at Chippewa.

Q. And there is no backwater there?

A. Another reason is that the observations of the Board of Engineers on Deep Waterways, while somewhat restricted in number and range are reasonably corroborative of the increment derived by the Lake Survey.

Another reason still is that the hydraulic conditions are the simpliest in the Niagara River of any of the three rivers considered.

Q. In what respect?

A. The Gaging Section is very close to the Buffalo gage at the head of the river. There are no backwater effects that need any consideration in the open season flow; and the corroboration of the three sections, which are so very different in their physical conditions, adds strength, not only to the mean volume of flow but to the increment as well. In speaking of these divergent or differing physical conditions, the measurements of the Niagara River were made in one place at the Open Section, where we get the whole river flowing in a single stream. In the case of the International Bridge, we have the whole river flowing in nine different streams. In the case of the Split Section we have the river flowing in two different streams, and we have a wide range of velocities as well.

The reason I give a lower precision to the St. Lawrence is because of some little doubt that has arisen in the late investigations of the Lake Survey as to the observations of 1900-1901. The range of stage was so little on the St. Lawrence that a slight inaccuracy in the group of observations the second year would vary the line quite considerably, and there appears from Mr. Richmond's investigations to be a slight inaccuracy in the second season's work. The reason of it is not very clear yet, but it has been considered.

In the case of the St. Clair River, the complexity entering from the backwater effect of Lake St. Clair is a thing which is likely to make the increment less determinable, and again in the case of St. Clair River the lack of a long range of lake stage. I believe it is a little over two feet there.

Now, the St. Clair River and its increment has the corroboration of very close checks in the three sections meas-

ured, and they are quite different so that my view of the lesser precision of the increment of the St. Clair grows out of that fact that I have mentioned, or the several facts I have mentioned. The mean volume of flow at the mean stage of the observations is doubtless one of the most accurate we have in this series of observations, in my judgment.

Q. What effect if any did your personal supervision at the Niagara River have upon your opinion, Mr. Shenehon?

A. I was, of course, intensely interested in the problem of measuring the flow of the Niagara River, and very much pleased at the close confirmation of the measurement in the Bridge Section as shown by the volume of flow of the Open Section. But when I went to the St. Lawrence River, which was also under my immediate charge, I had had all the experience of the work on the Niagara River in addition to my former work in river measurement and other forms of hydraulics. I had reached what appeared to me a little better method of work, and in gaging the three point section of the St. Lawrence, I regarded that as my masterpiece, if I may speak of it in that way. I believe the Section itself and the methods used there in many respects are excellent.

Mr. Austrian: What year was that?

A. That was in the year 1900. The reason why the final results in the St. Lawrence are not of the same precision, in my judgment, as those of the Niagara River, is simply the fact that we did not get the range of Lake stage or river stage at Ogdensburg. That was a matter of gaging only over a short period, and we did not have a duplicate section, you understand, there, except as the winter section at Nevins Point already referred to is considered. That winter section at Nevins Point on the St. Lawrence was only a partial corroboration of the accuracy. It was not as full as the corroboration we have of the Open Section and the Third Section on the Niagara.

I do not know that any statement in detail concerning that winter section has ever been put in this record. From the treatment at that time of the observations on the same principles that they were treated in my 1902 report for winter observations, the gage tender's gage at the Galope Rapids was used as the basis of judging whether the flow corresponded to the summer flow or not; and on that basis the two sections were in accord within somewhere in the neighborhood of 1 per cent., as I recollect it. But that corroboration is nowhere near as good as the corroboration of the Third Section of the Niagara River, and of course the Open Section

is a complete corroboration of the International Bridge, volume of flow. So I had all the direct supervision on the St. Lawrence that I had on the Niagara, and with all my experience there is a further advantage in the latter work.

Q. Did the Board of Engineers on Deep Waterways make any observations on the Niagara?

A. The observations made by the Board of Engineers on Deep Waterways derived a volume of flow and an increment for the Niagara River. During the last two months of the operations of that Board of Engineers, I was in charge of their Buffalo office, and Mr. C. B. Stewart was making the discharge observations, without any particular supervision or direction of mind. That was in the year 1898, July to September 1898.

Now the volume of flow as indicated by the measurements of the Board of Engineers was about 4 per cent. greater than the volume of flow indicated by my own measurements at the Bridge Section.

The main reason for the difference was in the measurement of the cross sectional area. As the area was sounded by the Board of Engineers, they used an 80 pound weight on a sash cord, throwing the weight upstream much as you sound with a lead line, and letting the weight and the line drop downstream with the current. The cross sectional area was, as I recollect it, about three per cent. in error. Aside from that, the error of coefficients and all other elements entering was simply 1 per cent.

In speaking of the Board of Engineers on Deep Waterways, I would like to read a statement from Mr. Haskell as to the difference in the volume of flow as indicated by the work of the Lake Survey and that of the Board of Engineers. This is on page 5323 of the report of the United States Lake Survey for 1900, Appendix III; and is the report of Mr. E. E. Haskell, assistant engineer.

Mr. Adcock: That is the Chief Engineer's report is it?

A. Yes, report of the Engineer, Appendix III, on the Northern and Northwestern lakes.

> "It will be observed that the results obtained by Mr. Shenehon for the discharge of the Niagara are somewhat smaller than those given by the Board of Engineers on Deep Waterways, as published by Mr. C. B. Stewart in his paper on discharge measurements of the Niagara River read before the Western Society of Engineers in December, 1899."

This report of Mr. Stewart was afterwards printed in the report of the board of engineers on Deep Waterways.

"The greater part of this difference comes from our having very much more data upon which to base the determination of the coefficients used in the reductions. The remainder comes from the smaller values used for the cross section, that is having been measured with more elaborate appliances by Mr. Shenehon, and hence with greater precision than I could obtain with the outfit at my disposal when I started to work for the Board. I mention this so there can be no misunderstanding regarding the values obtained by the Board and those published by this office."

Mr. Hopkins: That is all at the present.

Adjourned subject to notice.

FRANCIS C. SHENEHON, a witness recalled on behalf of the Government, testified further as follows:

Cross-Examination by Mr. Adcock.

Q. Suppose that for a certain channel similar in magnitude to those connecting the Great Lakes, but without such rapids or falls as occur at the Soo and Niagara, for a period of years, the elevation of the water at the upstream end had been as shown in the first column and the fall through the channel had been as shown in the second column of Haskell's Exhibit A, for Identification, February 25, 1914. And suppose that it were desired to obtain a discharge curve for this section that would represent the discharge of the period referred to the head at the upstream end, and suppose that there had been made a series of 27 observations under the conditions of columns 3 and 4, and that there was also available a series of 23 observations made with equal care under the conditions shown in columns 5 and 6, which, in your judgment, would give a discharge curve the more closely applicable to the assumed condition of columns 1 and 2?

A. I should not wish to answer that question without plotting the observations and investigating them in detail.

Q. You can do that by the next hearing can you not?

A. Yes.

Q. You testified first in this case in 1908, did you not Mr. Shenehon?

A. June, 1909.

Q. 1908, was the last time you made any measurements on any of these outlets, was it not?

A. I was Principal Assistant Engineer of the United States Lake Survey at the time the measurements in the Gorge Section of the St. Clair River were made. The measurements on that section were initiated at the time that I was Principal Assistant Engineer of the office.

Q. How much better qualified are you now to judge of the precision of a series of discharge measurements made by you on a large river than you were in 1908?

A. Well, I have given some considerable thought to things connected with river measurements, in connection with this case mainly, and in connection with my practice as a consulting engineer.

Q. How much more nearly correct would you consider your present estimate of the error of a series of measurements made by you at this time than it would have been for a similar series made by you in 1908?

A. I think that my judgment of the precision of the measurements made on the rivers of the Great Lakes has much to assist it at the present time. Let me say what I mean:—

Q. I hope you will confine your answer to your own measurements, the measurements you made yourself.

A. I can hardly do that, because my judgment is affected by the reports and conclusions that have been made and reached by the other men of the Lake Survey, and by computations made from those measurements by myself.

I was going to say that the reason I have a greater certainty as to the precision of these measurements now comes from the close corroboration of the volume of flow in the Gorge Section with that in the Dry Dock Section; those two sections checking within 1 per cent.

Q. I wish—

A. Just let me go on with this answer. In addition, we have the check of the sections made by Mr. Richmond in the delta of the St. Clair, which are within 1 to 2 per cent.

In addition it has been testified to, and I believe is correct, that the measurements in the Detroit River are in full accord with the measurements already made in the St. Clair River.

In addition, by interpolating the local supply for Lake Erie

as computed by Mr. Gardner S. Williams, there is full accord between the St. Clair River measurements and the Niagara.

In addition, the Third Section of the Niagara River has been measured, and this checks within 6/10 of one per cent., or within 1 per cent., let us say, of the prior sections, on the Niagara River.

In addition, the corroboration of the measurements of the Niagara River, which after interpolating the supply of Lake Ontario as computed by Mr. Gardner S. Williams, or Mr. Frederic P. Stearns, check within two per cent. the volume of flow in the St. Lawrence River. So that my judgment has been much assisted in reaching a conclusion that these measurements are of the highest precision.

Mr. Adcock: I will move to strike out all the answer of the witness, and I will ask the witness to answer the question which I asked him; and not discuss the measurements of particular rivers. I will ask the Commissioner to read the question.

(Question read as follows: "How much more nearly correct would you consider your present estimate of the error of a series of measurements made by you at this time than it would have been for a similar series made by you in 1908?")

A. Do you mean, Mr. Adcock, if I should go out now and make a new series of measurements?

Q. Yes, measurements of a river, made by yourself?

A. I should expect to better the prior work very little. I believe all this does affect my judgment, and would affect my judgment in going out to measure a stream myself; that the Lake Survey has bettered the methods that were used, in some little details.

Q. Suppose that you went out to measure the Mississippi River now, how much more acurrate would your judgment of the error be of those discharge measurements made at the present time than your judgment as to the discharge measurements made in 1908 of the same river?

A. I think if it were the Misssissippi River, I should not expect to get the precision we have gotten on the rivers of the Great Lakes.

Q. I am speaking of the Mississippi River?

A. I should not expect to get the same degree of precision on the Mississippi.

Q. I am asking you for your judgment of the percentage of error of the discharge measurements?

A. On the Mississippi River?

Q. Yes?

A. Under flood conditions?

Q. 26 measurements made at the present time as compared with measurements that you might have made in 1908?

Mr. Hopkins: Which he might have made in 1908, on the Mississippi River?

Mr. Adcock: Yes.

A. I think there would be very little difference in the precision; that is, with my present knowledge as compared with my knowledge in 1908.

Q. Then you mean to say, do you, Mr. Shenehon, that your estimate of the precision of the discharge measurements made in 1908 is as good as your estimate would be to-day?

A. No, I do not.

Q. Well, how much difference would there be, what per cent. better?

A. Let us understand what we are getting at here. Perhaps I do not quite understand it. Do you mean by that my precision of the Niagara River—

Q. No.

A —in the light of my present knowledge, as compared with what my estimate of the precision might have been in 1908?

Q. No, any river of the magnitude, say, of the Niagara River. I want your opinion as to how much better you are able to judge now than you were in 1908?

A. I feel that I judge with a higher degree of certainty now than I would in 1908.

Q. How much higher?

A. I can't state that in figures. I think my view at that time was that we could measure these streams within 1 per cent., and I do not feel that we can do much better than that on the streams of the Great Lakes; and the chances are in such rivers as the Mississippi, under the silt conditions, that the precision might be a little lower there. I have not, however, had any experience in a silt bearing stream, so my view of that is somewhat speculative.

Q. Well, would you say that your judgment was 50 per cent. better now than it was then?

A. I am afraid I can't measure my judgment in percentages.

Q. Well, maybe you could measure it in this way. How much more money would you spend on your judgment now than you would in 1908, if the question as to whether you would

spend the money were based upon your judgment as to the precision of measurements?

A I am afraid I can't help you on that.

Q You can't help me. Do you consider that Mr. Richmond, a witness for the complainant, is better qualified to judge of the accuracy of a series of discharge measurements made by himself, than you are now able to judge of a series made by yourself, at this time?

A You are getting into psychology now.

Q I am asking for your opinion as to Mr. Richmond's judgment of the accuracy of his measurement, as compared with your judgment of the accuracy of measurements made by you now,—a comparison?

A I regard Mr. Richmond as a man of excellent judgment, and he has made very full investigations. I should regard his judgment as very high.

Q Do you consider that he is better qualified, or that you are better qualified, to judge of those things?

A. I do not like to pass on my qualifications, in matters of this kind.

Q. We know the qualifications of Mr. Richmond?

A. Yes.

Q. And we know your qualifications; it is in evidence in this case.

A. Of course I am an older man, with possibly wider experience than Mr. Richmond; and I think that should be considered in answering the question.

Q. You would say the same thing as to Mr. Moore, wouldn't you? He is a Junior Engineer in the Lake Survey, the same as Mr. Richmond?

A. Yes, Mr. Moore is a man who has the experimental mind, I think, and is an investigator, and has excellent judgment I think; perhaps not quite as deliberate as Mr. Richmond in some ways; perhaps not having quite the judicial mind of Mr. Richmond; perhaps I could put it in that way.

Q. Taking them both together, do you consider that Mr. Richmond and Mr. Moore are better qualified in their combined judgment as to the accuracy of discharge measurements made by themselves than you were to judge of the accuracy of similar measurements made by yourself in 1908?

A. I should think it would be about an even thing.

Q. About an even chance?

A. I should think so.

Q. In this case, one equals two ?

A. I do not think you can put it in mathematical form, Mr. Adcock. The assumption of course is that a jury of 12 men give a better decision than a judge, but it is not always so.

Q. What length of time do you consider a proper one to allow for between the reading of the Buffalo gage and the corresponding discharge measurement at the International Bridge?

A. Eight to ten minutes.

Q. What did you use?

A. In the case of the International Bridge, I believe no time correction was made for lag. In the case of the Open Section, either eight or ten minutes; I am not certain.

Q. And the Open Section would be eight or ten minutes?

A. Yes.

Q. And the Open Section is about 2,000 feet—

A. Abouth 1800 feet below the International Bridge.

Q. Below the International Bridge?

A. Yes.

Q. What as to the Split Section?

A. Somewhere in the neighborhood of an hour, or possibly a little less.

Q. How do you establish this time?

A. The time interval between Chippewa and the Lake is about two hours, and I believe this is a little less than half way down the river; that is the location of the Split Section.

Q. And for the International Bridge and Open Sections, how do you establish that?

A. That was established by observations made from the International Bridge, in which current meters were run continuously in connection with the water gages, the Buffalo gage and the Section gage, and the curves of velocity and elevation of water surface of the Section and at the Buffalo gage plotted, in order of time.

Q. How many current meters did you run continuously?

A. My recollection is that we ran one.

Q. Where did you run it?

A. About mid stream of the International Bridge, as I recollect it. You understand, you are asking me questions concerning things that happened something over 15 years ago.

Q. Did you do that yourself, Mr. Shenehon?

A. I believe I started the observations, yet I am not positive of that.

Q. How long was this current meter run?

A. About half a day. Now, I have not seen those curves,

as I recollect it, since that time. I would need to refresh my memory of these things by actually getting out the curves and seeing them. They are in the records of the United States Lake Survey Office.

Q. Did you make any discharge measurements simultaneously at different places on the Niagara River?

A. No.

Q. To determine the travel of the discharge?

A. No.

Q. The change of discharge for change of elevation?

A. That depends on the fact that a meter running at a single station is an index, in a large way, of the volume of flow clear across the river. You could observe on a single station, one of the important mid river stations, and knowing the relationship of the various stations, you could write out in rather a crude way the discharge, possibly within 5 per cent.

Q. Would it have been as satisfactory a way to determine this change of discharge for change of lake stage to have run a series of meters at different points between Chippewa and the head of the river, simultaneously?

A. It would have been a scheme that would have been helpful, yes.

Q. As an engineer, do you consider that would have been a correct way for determining the change of discharge?

A. Let me say something else: You asked me if we had measured the discharge simultaneously several places on the Niagara River, would that have been as satisfactory, and I answered yes. Now, by calibrating the weir in the Whirlpool, and calibrating the weir at Suspension Bridge and that at Chippewa, we have measured simultaneously by weir measurements the flow of the Niagara River in four places at the same time; at the International Bridge, referred to the Buffalo gage, the Chippewa gage, the Suspension Bridge gage, and the Whirlpool gage.

Whenever the water is at a certain elevation at Chippewa, there is a certain amount going over the Falls, so it is just as good as having a current meter measurement there, since the weir is calibrated. Whenever Lake Erie has a certain elevation, there is a certain amount of water going down the river. When it is a foot higher, there is around 22,000 cubic feet more; and we have corresponding elevations on the weir at Chippewa, so that we have the two simultaneous measure-

ments of out-flow suggested by you, so that we get the time of travel in that way.

Q. When you say you know the discharge of the Niagara River, you know it from these so-called measurements you have put in evidence, current meter measurements?

A. We have the current meter measurements of the International Bridge Section, the Open Section, and the Split Section, and we have the simultaneous gage readings corrected for lag at these other points I have just mentioned, so in the end we arrive at a discharge equation for the four different points; elevation at Erie; elevation at Chippewa; elevation at Suspension Bridge, and elevation at Whirlpool.

Q. How about the accuracy of those calibrations?

A. Practically exact, as indicated by the curves put in, in this case. When I say exact, I mean with the accuracy that we have for the discharge at Buffalo, with possibly a little trace of inaccuracy coming from the transfer, but it is very little.

Q. Then if a rise should occur at the Buffalo gage of, say, .2 of a foot, you would expect the full effect would be felt at the Bridge in about eight minutes, is that correct?

A. I think the "full effect" is not quite a correct statement. There would be a little reservoir effect in between the Bridge and the—

Q. What percentage of the effect?

A. I can't state that as to percentage.

Q. Nine tenths?

A. A pretty large percentage of the effect.

Q. About .9?

A. That would depend, Mr. Adcock, on the length of time during which the rise took place. If this .2 rise took place in two hours, you would probably have substantially the full effect. If it took place in 20 minutes, you would get a little less. I could not give the exact percentage.

Q. But you assumed, in deriving an increment there, that the full effect was obtained in eight minutes, didn't you?

A. I do not think that is involved. We were probably in error a little, one way or the other; and it would not be substantial in the end whether we made any time correction or not.

Q. Then your proposition is there was no use at all of making any correction there for the lag, is that right?

A. I think it added very little value. The correction of ten minutes probably decreased the residual a very slight

amount. It probably had no effect whatever on the final conclusion.

Q. Then am I to understand it did not make very much difference where the lake level was with reference to the time the discharge measurement was made?

A. No, I do not mean that.

Q. In deriving the increment?

A. No, within the limit of ten minutes, it made very little difference.

Mr. Hopkins: Q. Did you mean increased the residual or decreased it?

A. If we did not observe this little lag of ten minutes, the residual would be a little bigger there; the residuals are a little bigger on the Bridge Section on that account, but the conclusion in the end would be the same, substantially.

Q. The Buffalo gage is about three miles from the Bridge, isn't it, or the Bridge is about three miles from the Buffalo gage?

A. Somewhere in that neighborhood.

Q. And the Chippewa gage is about 20 miles from the Buffalo gage?

A. Yes.

Q. Assuming that there was a sudden lowering of say two tenths of a foot at a point an equal distance down stream from the Bridge, and the Buffalo gage remained stationary, how long would you expect it to be before the full effect reached the Bridge?

A. That is three miles down from the Bridge? Oh, I should imagine in the neighborhood of ten minutes.

Q. That is it would be about the same as the effect from the rise at the Buffalo gage, is that correct?

A. I suppose so; I should think so.

Q. There would not be any difference. You heard the testimony of Mr. Sherman Moore, a witness for the Complainant, relative to his observations of discharge in the Chicago Sanitary and Ship Canal, did you not?

A. Yes.

Q. Do you consider his gagings accurate and reliable, that is the gagings he made on the—

A. I have not given any detailed study to the gagings of Mr. Moore in the Sanitary Canal.

Q. Knowing Mr. Moore's work, what would you consider it to be?

A. I should expect it would be accurate, good work.

Q. Within what percentage?

A. I should think Mr. Moore could get the discharge of the Sanitary Canal within 2 per cent., and possibly a little better than that.

Q. Do you think he did get it within 2 per cent.?

A. I don't know. I have not examined his observations sufficiently to know.

Q. You were present and heard him testify about them did you not?

A. Yes.

Q. And the methods that he used?

A. I do not recollect now just how many measurements he did make. It was not an exhaustive, long piece of work.

Q. You heard Mr. Ray comment upon those measurements, didn't you?

A. Yes.

Q. The fact that Mr. Moore considered them reliable and accurate, would that have anything to do with your judgment?

A. Yes, Mr. Ray is a man of very excellent judgment, as I view it.

Q. Did he determine the time of travel of an increase of discharge from Lemont to Willow Springs, as you remember?

A. Yes.

Q. What was the time, and how did he determine it?

A. It was determined by the gage readings, as I recollect it. I am not certain whether the change in volume of flow with a change of gage openings at Lockport was involved. I have not given any large consideration to this with a view to testifying. It was not testified to in my direct testimony.

Q. Do you remember the time from the power house to Lemont, as stated by Mr. Moore?

A. I believe it was at the rate of about a mile in three minutes.

Q. That would be about 30 minutes, assuming it was ten miles?

A. Yes.

Q. Do you think the methods which Mr. Moore used to determine the length of time for a change of discharge was accurate?

A. Well, it should always be understood that in a case of that kind, the gage will not give you the full value in the change of flow. In other words, we have the same condition in any stream; the first thing that must be done on opening the

gates at Lockport is to draw off a certain volume of water; the reservoir effect comes in. And the same thing comes in the Niagara River and the St. Clair River and the St. Lawrence. The lower gage will not show for a sharp change in Lake Erie, for instance, the same relative change below, because part of the water has been used up in reservoir effect, either plus or minus.

Q. That is the same general principle would be applied to the conditions on the Niagara, St. Clair and St. Lawrence Rivers that would be applied here on the Drainage Canal?

A. Oh, yes.

Q. That is am I to understand that there would be a crest which would give a change in the stage of the water, and that the discharge would follow at some time after that corresponding to the change in elevation, at a certain place either up or down from the point you are making your gaging?

A. I stated in answer to your question concerning the Bridge, that the length of time in which the water is rising has some considerable influence on that. If you have a small rise in a relatively long time you get, at the intermediate point, practically the full value in discharge of the gage rise.

Q. Assuming for instance that the Buffalo gage should rise a foot, the elevation of the lake should change, so that it should be a foot higher. Now, there would be a crest that would travel down to the International Bridge in about eight minutes, wouldn't there be?

A. Yes.

Q. How soon would there be a change of discharge at the International Bridge, to correspond with the elevation of the lake at the Buffalo gage for this changed elevation?

A. If the rise was at the rate of an inch an hour, something of that kind, the discharge would be practically undiminished. That is the elevation of the gage at the International Bridge would correspond to the volume of flow under quiescent conditions.

Q. That is the discharge would change just as quickly as the crest?

A. In a very slow rise.

Q. As the gage would rise?

A. Where the lake was rising slowly. If however, there was a seiche that came up, where it rose a foot in a short time, the volume of flow at the beginning would be a little greater, of course, at the International Bridge, due to the increased

slope. And as it traveled down the river, the reservoir effect would come in and that would be lessened. So when you got to Chippewa—

Q. Suppose there would be a sudden change of three or four inches. That is quite usual, isn't it, at the Buffalo gage?

A. You mean in an hour or two?

Q. Say in 20 minutes.

A. Well, under those circumstances you would have a higher velocity, a higher flow than you would get for a slower rise, on account of the increased slope.

Q. That is at the time that the crest reached the International Bridge, the discharge would be greater at the International Bridge than it should be according to the elevation of the lake, is that it?

A. The general proposition is that a rising stage gives a little higher volume of flow at the up-stream or initial weir. I believe the observations will show that; the rising stages will show a little higher discharge than the falling stages.

Q. Do you think they will show a higher discharge than a continuous stage of the Lake?

A. Yes, a rising stage would show a slightly higher volume of flow than a quiescent stage, or falling stage. These are very small quantities, you understand.

Q. I am not asking you about that.

A. I think in my original testimony, I indicated perhaps 1 to 2 per cent. Possibly that is on the large side.

Q. Now the method which Mr. Moore used with reference to determining the travel or the lag was similar on the Drainage Canal to the method which was used to determine the same thing with reference to the Niagara River. Isn't that true?

A. I rather thought that he used the gages rather than current meter measurements. And yet, I am not sure. That is his continuous gage record, I believe, does parallel the line of the volumes of flow.

On examination of the plot made by Mr. Moore entitled: "Elevations and flow in Chicago Drainage Canal from measurements of December 16, to 22, 1913," being (Moore's Exhibit 5 of Feb. 5, 1914) I find that the volumes of flow are also plotted for the different hours, as well as the gages or the gage readings at Lake Michigan, Willow Springs and Lemont.

Q. The question was: Was it a similar method to the one which was used in the Niagara River to determine lag?

A. Yes, the method is similar.

Q. Now you said it would take how long for the crest to travel to the Split Section from Buffalo gage?

A. That is an estimated value, and I had in mind Mr. Richmond's statement of one hour.

Q. One hour?

A. Yes.

Q. Assuming that the elevation of the lake at the Buffalo gage should rise a foot, the crest would be apparent at the Split Section in one hour, would it not, about that, approximately one hour. Would the discharge at the Split Section correspond, at the time the crest arrives at the Split Section, to the change of the stage of the lake?

A. I think there would be a little lesser discharge under those circumstances, that is assuming a fairly rapid change.

Q. The discharge would not be as great as it should be according to the change of stage at Buffalo gage, is that right?

A. A portion of the water is being used up in reservoir effect in between. And if the gage were going down, the converse would be true; and the effect is a compensating one, so far as the volume of flow is concerned.

Q. If an allowance of time were made for the amount required to fill the storage, is it then your opinion that the discharge at the Split Section would correspond to that due to the elevation of the Buffalo gage, with the time interval indicated by the transmission of the wave, plus this period of storage?

A. I should not care to answer that without some consideration. I do wish however to say right here that no correction was made in the Niagara River for reservoir effect. That was a point that came up in Mr. Williams' testimony, in which he suggested that he assumed that we had made corrections for reservoir effect. That is not so. The correction for reservoir effect would make the residuals a trifle smaller, but would have no influence on the final result.

Q. What percentage of the full effect would be felt in an hour in the discharge?

A. I could not tell you that, Mr. Adcock. I have some curves in my trunk which will give some information on that point, in which the gage in the Gorge and at Suspension Bridge is the basis, so that we can find the time of travel and the percentage of flow, the lessened percentage of flow that comes with sharp rises, or in falling water the converse. I

would be very glad to bring those up; then we can discuss that intelligently.

Q. In getting your increment, in deriving your increment, do you determine the percentage of the full effect that is felt at the time that the wave reaches the gaging section?

A. The error coming in an individual measurement from this cause is plus in one case and minus in another, and in the aggregate in the many observations which we have, it is eliminated, compensated. This shows very clearly in the observations plotted in the Gorge and at the Whirlpool for single days. The observations themselves show that the volume of flow passing over the rapids, through the Whirlpool Rapids and the Lower Rapids, is very exact as compared with the volume of flow passing out of Lake Erie; that is for an eight hour stretch, eight or ten hour stretch. So that it is a little thing except as you regard the lag coming from a fairly sharp rise.

Q. You assumed that those errors offset one another in the number of gagings, that is your theory is it?

A. Oh yes, I am very positive of that.

Q. That is it would be impossible for you to use words that would really express how positive you are, is that true?

A. (No response.)

Q. You are aware, Mr. Shenehon, that yesterday Lake Michigan at the Chicago gage changed about 5 feet in 20 or 30 minutes, the stage of the lake?

A. That fact has been mentioned to me. I have no observations indicating that, but I understand there was a seiche at this end of the lake that had very considerable value. I have never heard of one as large as this one, which I heard spoken of as about 5 feet, I mean at such short intervals.

Q. There are changes of that character in the stage here and at other points of Lake Michigan, Huron and Erie, in perhaps not that short a time but in an hour or so, aren't there?

A. Yes.

Q. Quite frequently?

A. I should expect this to be a very unusual phenomenon. Mr. Cooley I believe, mentioned this seiche in this vicinity as of short period, but of rather slight rise, magnitude. I should imagine that the records of the Sanitary District must be full of information as to the travel of such a seiche down the canal.

Q. On Lake Erie there are sudden changes of greater magnitude than that, aren't there?

A. I don't recall any seiche of this short period. The

Lake Erie seiche is something like eight hours long as I recollect it; that is from end to end of the lake.

Q. That amounts sometimes to 10 or 15 feet, doesn't it, 10 to 12 feet?

A. That is very exceptional. There are I think records where the lake has gone up as much as 8 feet, but it is not within my experience. I had great difficulty in securing a range of a little less than 4 feet, which we secured in the Niagara River during the time that I was observing there.

Q. That was at the Buffalo gage?

A. That was at the Buffalo gage. That includes the years 1898 to July 1900, inclusive. That is the open season, and it includes also the periods in 1907 and 1908. We were looking for just such seiches of that kind, with full equipment ready to take advantage of them, and they didn't come along very frequently.

Q. When you speak of the mean of a series of discharges measured at certain mean elevations of the lake being in error a certain per cent., do you assume that the elevation of the lake is also in error by some further amount, or do you consider that the elevation is corrected and all the error is represented in the discharge as referred to that elevation?

A. The error in the gage—and I speak now of the Buffalo gage—is exceedingly small. In the mean of a number of observations, it is probably not greater than one to two hundredths of a foot. That would be a quarter of one per cent. of the outflow. I know of no reason why it should be persistently of one sign rather than of the other; just as likely to be plus as minus.

Q. So they would offset; in the end you would obtain accuracy because the errors would be offset, is that correct?

A. Yes, it is compensating. Of course the matter of the error of the gage seems to me very conclusively settled, when I consider the eliminating of the Buffalo gage entirely, as was done in the exhibits put in by me in this case. We took the gage at Suspension Bridge and the gage in the Whirlpool and eliminated the Buffalo gage, and by water level transfers got our increment out with respect to Cleveland. So I feel that the error in the gage is an exceedingly small thing; needs no large consideration.

Mr. Adcock: Now Mr. Reporter will you read the question?

(Question read.)

A. Let me give a specific case: When we say that the volume of outflow of the Niagara River is 219,000 cubic sec-

onds feet at elevation 573.00, it involves the gage as well as the volume of outflow.

Q. What per cent. of error do you ascribe to the gage elevation?

A. Well, we regard the gage as a fixed thing; 573 means 573. We regard the gage as accurate and throw all the error in the discharge. The errors of individual observations are so great compared with the error in the gage that this seems to be the proper procedure.

Q. Is that what you had in mind when you stated that the St. Clair increment was likely to be less accurate than the Niagara River, on account of the shorter range of Lake elevations?

A. No. If you had observations of equal precision, and in one case you had a range of lake stage of two feet, and in the other case you had a range of four feet, the precision would bear the same ratio as the range. In other words it would be twice as precise; any error would be half as great in the case of the four foot range.

Q. You give that as one of your—

A. (Interrupting) I wish to add a little something to that: I do not mean to say that is all in the case of the St. Clair. We have this intricate, complex situation of the outflow being governed by Huron's elevation, as well as a backwater effect from Lake St. Clair, so we have there an exceedingly complex condition. It is not alone the range of two feet; it is this other complexity added, that had made the difficulty in the St. Clair River.

Q. You do believe that the lesser range of lake stage has an influence upon the accuracy of the increment in the St. Clair River, as compared with Niagara?

A. You mean that is one of the elements, the lack of range as compared with the Niagara, for instance? Oh, yes.

Q. You are again positive about that, are you, Mr. Shenehon?

A. Yes.

Q. What was the range of Lake Huron stage at Harbor Beach during the St. Clair measurements?

A. It was a little over two feet, as I recollect it. Is that what you mean, the elevation corresponding to the observation?

Q. Yes. Suppose that on any of the rivers connecting the Great Lakes there had been made by the Lake Survey 147 measurements of discharge covering a range of lake stage

of 0.76 feet, with what degree of accuracy would you say the discharge of the river in question was known, corresponding to the mean of the elevations at which the discharges were observed?

A. So far as the compensating errors entering into this group of 147 observations are concerned, it would be very little, probably not over one-tenth of one per cent.; but the fixed error, of course, due to cross section, due to velocity coefficients, due to any fixed inaccuracy of the meter measurements should be added to the accidental or compensating error.

Mr. Adcock: Will you read the question Mr. Reporter, and see if we can get an answer to the question.

Q. (Question read as follows: "Suppose that on any of the rivers connecting the Great Lakes there had been made by the Lake Survey 147 measurements of discharge covering a range of Lake stage of 0.76 feet, with what degree of accuracy would you say the discharge of the river in question was known, corresponding to the mean of the elevations at which the discharges were observed.)" Assuming that the measurements were made by the Lake Survey, and they used in those measurements the accuracy which they claim to use, and which you probably think they do use?

A. Is that a question?

Q. That is a question?

A. I thought I answered your question. Haven't I answered that question?

Q. No, because I assumed that they probably have determined the cross section and all those other things, and they rate their meters, and all those things.

A. Well, are you asking for some particular river now, or any river?

Q. I am asking you about any river?

A. Well, I should say that we know the discharge for that group within 1 per cent.

Q. Suppose that upon the same river—

A. I would like to qualify that statement a little bit. We have in the Niagara and in the St. Clair what is known as the "slope cycle," due to growth of weeds; and a group of observations made at some particular time might include that; might be the time when the weeds were the greatest, or might be in the time when the weeds were in the least development, so that there is a possibility of error coming in there; and I am assuming in this answer that this 147 contains all normal weed conditions.

Q. Suppose that upon the same river we had 150 similar observations covering a range of lake stage of 0.98 feet, not included in the preceding group, made by the same Lake Survey that we speak of?

A. Same number of observations?

Q. No, 150.

A. Approximately the same.

Q. And the same assumption as to the supposed accuracy?

A. Practically the same, 1 per cent. say.

Q. That would be 1 per cent.?

A. That was a range of 0.98 on that last one?

Q. Suppose that you know the discharge of a certain river at a certain elevation within 1 per cent., and suppose that you also know the discharge at another elevation of the same river within 1 per cent., and assume that the discharges were 203,382 and 187,082 cubic feet per second, within what per cent, of accuracy would you know the difference between them?

A. What is the difference of elevation between the two?

Q. We haven't that yet, just the difference.

A. These were determined from the number of observations given, 147 and 150?

Q. Yes. Assume you knew each of them within 1 per cent. (Question repeated.)

A. If it be assumed that the 1 per cent. in this answer is just as likely to be on one side as the other, the error may be as great at 25 per cent. That is of the difference there, it may be greater or less by 25 per cent. I should not expect however the 1 per cent. to be of an accidental kind so that it would not be as great as that, the error.

Q. That is the maximum would be 25 per cent.?

A. Yes, assuming that the whole error of 1 per cent. in these observations is of the accidental kind. It may be just as likely on one side as the other, then you would have a maximum of 25 per cent.

Q. Didn't you limit that kind of an error to one-tenth of 1 per cent.?

A. No, the limitation to one-tenth of 1 per cent. was on the basis of the residual of 1 per cent., a mean residual of 1 per cent. in the observations, and that does not mean necessarily that is all eliminated.

Q. What do you consider to be the most reasonable error? You have given the maximum of 25 per cent.

A. You haven't given the range have you between these two groups?

Q. Not yet. We are asking about the accuracy of the difference. We have not got to the increment.

A. Well, the error, under the assumption of the full error being of the accidental kind, would be somewhere between 1 per cent. and 25.

Q. What would you say it would be nearer, the 1 per cent. or nearer the 25 per cent.?

A. Well, I think I would wish to know what particular place you were talking about.

Q. I am speaking of the difference?

A. Is there a question?

Q. Yes? Would it be nearer the 1 per cent. or nearer the 25 per cent.?

A. I don't believe I can answer that definitely without knowing the particular location. You asked me concerning gages a little while ago. I am not quite free to say that in two groups on the St. Clair, for instance, that we know our gage relations quite as accurately as we do in such simple cases as we had on the St. Lawrence and the Niagara.

Q. I am not asking you to assume any inaccuracy for the determination of the gage?

A. You are reaching a point now where you have a difference.

Q. Yes, I am asking for the difference. I am asking for the per cent. of error in the difference, per cent. of accuracy in the difference, rather.

A. Well, I should say it would be an even thing whether it is 1 per cent. or 25 per cent., and either side.

Q. If the elevations were 580.92 and 580.35, and the difference in elevation between the two discharges was 0.57 feet, within what degree of accuracy would you know the change of discharge for a change of elevation of 1 foot?

A. Well, you would divide the error which I have just given by this quantity, 0.57.

Q. That is you would divide 25 per cent. by that?

A. That is if you are securing the increment, if that is what I understand you to mean. You want to know what the increment would be?

Q. We have asked what the increment would be for a change of 1 foot?

A. The error of the difference would not be any greater whatever the interval between them; that is already determined.

Q. I do not get that?

A. I have already given you the percentage of the error of the difference between two quantities.

Q. Yes. Now I am asking you within what degree of accuracy would you know the change of discharge for change of elevation of 1 foot, assuming that the range between the two—

A. That is my answer. That becomes an increment, under those circumstances, under our definition in this case. It would be 1 divided by 0.57 to 25 divided by 0.57. It would be from say 2 per cent. to 44 per cent.

Q. Would it be nearer 2 per cent. or nearer 44 per cent.?

A. It is an even thing.

Q. It might be one or the other?

A. Yes.

Q. That then would be the error in the increment, is that correct?

A. Under those circumstances I should think so.

Q. (Question read as follows): "If the elevations were 580.92 and 580.35 and the difference in elevation between the two discharges was 0.57 feet, within what degree of accuracy would you know the change of discharge for a change of elevation of 1 foot?"

A. I wish to make this reservation: What I have stated thus far is on the assumption that the error of 1 per cent. we are talking about here is an accidental error, just as likely to be on one side as the other, which is not true for the most part of the observations with which we have to do in this case.

Q. How much would you want to reduce it, having in mind the observations which have been referred to in this case?

A. If I were speaking of the Niagara observations, I think I would divide that by about four, possibly by a bigger divisor.

Q. How about the St. Lawrence? We would like to hear from you on that?

A. The St. Lawrence River has had a change of regimen since the original observations, and I myself have not investigated the observations since the building of the Gut Dam. The building of the Gut Dam changed the outflow by about 5½ per cent., and changed the increment, I presume, in some measure, probably by about the same percentage.

Q. When you say outflow, you mean capacity?

A. The volume—

Q. The capacity of a river?

A. Yes. That is the building of the Gut Dam in one of the three channels at the Galops has changed the conditions of flow as measured by me in 1900 and 1901. We had I believe

only 93 observations and those were in two groups, the lower ones being in one season and the upper ones in the second season. It appears at the present time that an error did enter there. This is still in the melting pot, and we don't know our increment as accurately, or we did not know our increment as accurately on the St. Lawrence as indicated by my original testimony; that is, that is the indication from the present investigations.

Q. And you are willing to take those indications now and testify to them?

A. The new increment, as derived by the Lake Survey.

Q. When it gets through the melting pot, then you may have another opinion, is that correct?

A. My opinion as to the increment under present conditions of the St. Lawrence is based on two things; one is the testimony of the Lake Survey men in this case, the men who have been engaged upon that work, and the other is the investigation by the methods of fluctuations which indicates an increment between eighteen and nineteen thousand. While this method of fluctuations has distinct limitations, is a rough check on the increment and is not to be entirely disregarded.

Q. That is the St. Lawrence River?

A. I am speaking of the St. Lawrence now.

Q. That is the increment there is between eighteen thousand and nineteen thousand?

A. No, I think it is about twenty one thousand. I think the testimony indicates about twenty-one or twenty-two thousand.

Q. And the error that crept in there was an error that may result from a somewhat disturbed condition in the bottom of the river?

A. No, it is not charged up to that.

Q. Error in the determination of the cross section?

A. No, the cross section checked almost exactly on the second determination.

Q. Wasn't there some question as to whether you got on the right line when you first measured?

A. That does not enter.

Q. That does not enter?

A. No.

Q. Then is it in the determination of the coefficients?

A. They checked almost exactly, the second determination with the first.

Q. Just what error did creep in?

A. There seems to be a little acceleration of the section;

that is, that is the indication. As I say, that is in the melting pot, so that the second season's observations may have been taken a little further downstream, not using the overnangs as we used them in the first season's work, and using lighter weights, and that is what appears to be the cause of the error of possibly 1 per cent. in the second season's observations. Whether it is so, I do not know.

Q. The melting pot is the so-called regular army that was mentioned by Mr. Wilkerson the other day?

A. That is that very distinguished body of men known as the Lake Survey.

Q. Such as Mr. Richmond, Mr. Moore?

A. Mr. Ray.

Q. With very large experience in engineering affairs?

A. I know of no men who have had better experience in river gaging than the gentlemen you are speaking of, unless I should indicate Mr. Haskell, and other men who have been connected with the Lake Survey.

I believe the error in the St. Lawrence increment as originally derived, and as finally derived, is somewhere in the neighborhood, that is the difference is somewhere in the neighborhood of 10 or 15 per cent. The original increment was stated with respect to the Ogdensburg gage. It was also stated on our Exhibit Number 2, U. S. Exhibit Number 2, that the Gut Dam has since been built, which would reduce the increment about 5½ per cent. The change from Ogdensburg to Oswego means two per cent. more. That is 7½ per cent. My own estimate of the error of the increment was ten per cent. Take that as negative, and you are pretty close to the new increment derived, testified to by the Lake Survey.

Q. You prepared the original exhibits of the complainant in this case, did you not, Mr. Shenehon? You prepared the original exhibits 1, 2, 3 and 4 in this case, didn't you?

A. Yes, they were prepared under my direction.

In answering a preceding question, I stated that the error of the difference of two quantities was between 1 and 25 per cent. This would be also the error of the increment under these conditions, instead of the 2 to 44 per cent. previously stated.

Q. Then you were in error when you said the percentage of accuracy of the increment was dependent on the difference of elevation considered. That is what I gather from your correction?

A. No, I don't wish to be interpreted as making that statement.

Q. I call your attention in this connection, Mr. Shenehon to a statement made on page 2804 of your direct examination in which you were asked this question:

"Q. What effect does that range or lack of range have upon the result?" (You are speaking of the increment.)

"A. I think no engineer, even Mr. Williams, would wish to state that there was any consequence whatever in an increment derived with a change of lake elevation of .03 of a foot.

"Q. Why not?

"A. The precision of the increment is proportional, other things being equal, to the range in the level of the lake between the observations. If one should take a set of observations with ten in each group,—two sets of observations with ten in each group, and there was a foot difference in elevation in the lake stage between the two, the error in the increment would be likely to be as much as ten per cent. or more; and where you took only .03 of a foot instead of a foot, why the increment is likely to be several hundred per cent. in error. By taking a large number of stages, the error in the result would be considerably diminished, but the method in my judgment, the method of applying this treatment is not the proper one?"

A. That statement that you have read is correct. I need to think this matter out a little bit, here. There is a little question between the original percentage of the total volume applied in each case, and then the final percentage of the increment itself.

If the volume of flow is ten times as big as the increment, the percentage error in the increment would be ten times that of the volume of flow; twice ten times, if we had errors of opposite signs; then you would divide that error by the range to get the precision of the trend of the line itself.

This question you have asked me is a little confusing, and I wish time to straighten that out.

Mr. Adcock: Certainly.

The Witness: My statement in my original testimony is correct.

Mr. Adcock: I simply called your attention to it to refresh your recollection, that is all.

The Witness: It is correct.

Mr. Adcock: I assumed you still wanted to abide by your testimony.

The Witness: Oh yes, that is correct in my original testimony.

Mr. Adcock: I am asking you now with reference to

whether you were in error when you said a little while ago that the percentage of accuracy of the increment was dependent on the difference of elevation considered?

A. That is true, it is dependent on the difference in elevation considered.

Q. Assume that at a certain mean elevation the mean discharge of a large number of measurements is 300,000 cubic feet per second, and assume that this might be in error 1 per cent., then the true discharge might be anything between 303,000 and 397,000 cubic feet per second, might it not?

A. Yes.

Q. Assume that at another mean elevation the mean of a large number of discharges was 200,000 cubic feet per second, and that this might be 1 per cent. in error, then the true discharge might be anything between 202,000 and 198,000 cubic feet per second, might it not?

A. Yes.

Q. Assuming that these mean elevations were 1 foot apart, what would be the maximum, minimum and mean values of the increment?

A. That is 300,000, starting?

Q. Yes, 300,000 and 200,000?

A. That would be about 2 per cent.

Q. No, I am asking you the maximum, mean and minimum values of the increment?

A. What is the range?

Q. 1 foot?

A. That would be 1 per cent.

Q. I want the quantities?

A. That would be 105,000.

Q. That would be the maximum.

A. 100,000.

Q. That would be the mean.

A. And 95,000.

Q. What is the maximum percentage error of the increment?

A. 5 per cent.

Q. Assume the elevations were .5 feet apart, what would be the maximum, minimum and mean values of the increment?

A. (No response.)

Recess to 7:00 P. M.

May 12, 1914.

After Recess, 7:00 P. M.

FRANCIS C. SHENEHON resumed the stand and testified further on cross-examination as follows:

Q. (Question read as follows: "Assume the elevations were .5 feet apart, what would be the maximum, minimum and mean values of the increment?")

A. The increment would be 210,000, 200,000 and 190,000 as extreme under these conditions.

Q. Respectively?

A. Respectively.

Q. What is the percentage error of the increment?

A. Five per cent. on either side.

Q. That is the same answer as to the question where the range was one foot, isn't it? Five per cent. on either side?

A. If you take your difference, a certain fixed quantity and have your error a certain percentage of that, then the percentage of the increment is the same. But that is not the case we have in the rivers of the Great Lakes?

Q. I am asking you whether this is the same percentage error you had when the difference was 1 foot. It is, is it not? That is 5 per cent on either side?

A. It would not make any difference, if you start with a certain difference, the percentage error in that; it is independent of the range, but that is not the case we have on the Great Lakes.

Q. You are still positive about that, Mr. Shenehon?

A. Yes. Perhaps I would better illustrate that, so as to make it quite clear, and to make it quite clear that my statement in my direct testimony concerning this .03 of a foot is corroborated. May I state it?

Q. Certainly. We are always ready to receive information.

A. I want to take a case where the volume of flow is say 200,000 cubic feet per second, and the error, we will assume is 1 per cent., or 2,000 feet. I would like to keep that 2,000 fixed, for simplicity.

Q. 2,000 what?

A. 2,000 cubic feet. Now, when the lake under these conditions has gone up one tenth of a foot, we have a difference of 2,000, according to our increment, but our error is 2,000, so the error is 100 per cent. of the difference. And if we

should derive an increment, the error of that increment would be 100 per cent.

Now, when the lake has gone up another tenth, two tenths in all, the difference is 4,000, while the error is 2,000. We have an error of 50 per cent., and the error in the increment from that would be 50 per cent., and so on until we reached 220,000, the lake having gone up a foot, the error being 2,000 and the increment 20,000; the increment is then in error 10 per cent.

If, instead of the lake going up one tenth of a foot it had only gone up .03 of a foot, we would have had an increased quantity there of 600, while our error is 2,000, so we would have had an error of 333 per cent. in our increment. That is the case, except the values of the increment are different as referred to in my direct testimony. The increment, I believe, in that case was a larger one, so the percentage of error would be a little smaller.

Q. You are assuming in that instance, Mr. Shenehon, that your error of discharge is always 2,000 cubic feet per second?

A. Yes; it is approximately 1 per cent. of our base quantity. If we regarded it as 1 per cent., it would not be that, growing a little bigger as we increased the volume of flow. But to illustrate the case, this does it very simply, and to my mind very satisfactorily, indicating that the error, the percentage of error in the increment is substantially as the range considered. That is if you have a range of 1 foot, and you have a certain error in your increment, when the range is four feet, you have one fourth of it, and it comes about in just that way.

Q. How do you apply that to the situation which was presented here in the hypothetical question which I asked you?

A. Well, the reason is because you have taken a big difference.

Q. I have taken .57 of a foot.

A. No, a big difference in the volume. You have taken a difference there in the volume of so much that the 2,000 or the 1 per cent. becomes a relatively smaller quantity. Having established your percentage quantity, then of course dividing by your range does not alter that fact.

Q. Assume that your discharge at a certain elevation was 200,000 cubic feet and the error was 1 per cent.?

A. Yes.

Q. At another elevation the discharge was 190,000.

A. And the same error, 1 per cent.

Q. What would be your maximum, minimum and mean values of the discharge in the first case?

A. Well, assuming one per cent., that would be 200,000 for absolute, 202,000 maximum, 198,000 minimum.

Q. And in the second case?

A. 190,000, 191,900 and 188,100.

Q. What results do you get?

A. 10,000, 13,900 and 6100. Those are the differences.

Q. Those are the differences?

A. Those are the differences, yes.

Q. Assume these mean elevations were 1 foot apart, what would be the maximum, minimum and mean values of the increment?

A. The increment would vary between plus 39 per cent.—

Q. No, I am asking you for the values of the increment?

A. This would be the values of the increment.

Q. Just indicate it?

A. Between 13,900 and 6,100.

Q. What is the percentage error of the increment?

A. 39 per cent. From plus 39 per cent. to minus 39 per cent.

Q. Suppose these mean elevations were 0.5 of a foot apart, what would be the maximum, minimum and mean values of the increment?

A. The percentage error has already been determined by the difference of 10,000, and the assumed percentage, so it does not vary with the range, in the particular way in which you ask the question. It is dependent on the range, as indicated by the smallness of the difference.

Q. Then the range has no effect upon the value of the increment?

A. The percentage error of the increment varies substantially as the range, as previously stated.

Q. Then how do you make that out in the assumed case?

A. Because the 10,000 indicated here, the difference is a value depending upon the range. For instance, if your increment is 20,000, the 10,000 indicates that your range is half a foot. That is the thing that determines the percentage error in your increment; the relative size of the difference, and the quantity which is the error. If the difference is 10,000 and the error 2,000, you see that it is a relatively big percentage of the difference, and that is how the increment is dependent for its precision on the range.

Q. I am a little dense: I wish you would explain further?

A. It is this way: Take the case I cited where the volume of flow is 200,000. One per cent. of that is a relatively large quantity, and 2,000 compared say to the difference coming with half a foot change in stage, say 10,000, so if you divided the 2,000 by the 10,000, you see you have got right there a 20 per cent. error indicated; and if that may be either side, of course the range of values doubles up; so that is the reason. It is the size of the difference as compared to the size of the percentage of a big quantity which is the volume, that is what determines it.

Q. The difference which you used in the last instance here was small as compared with that in the first instance, wasn't it? That is the 100,000, and 10,000?

A. Yes, and we found in the case where we had the big quantity indicating a large range that the error of the increment is 5 per cent., between plus and minus 5 per cent.

Q. But the percentage of error in the increment is the same for a foot as it was for 0.5 of a foot, as you worked it out, wasn't it?

A. With 100,000 as a difference, we have an indication right there of between 4 and 5 foot range.

Q. I know, but on the basis of the second assumption?

A. I think you are—

Q. That is it was the same percentage of error where the difference was one foot as it was where it was five tenths of a foot?

A. As I stated, the size of the difference in relation to the quantity discharged, percentage error; that is in the case above there the size of the 100,000 as compared with the error of 1 per cent., 3,000 or 2,000 for the smaller quantity. That is what determines the thing.

Q. Mr. Shenehon, you have submitted certain charts showing gage relations between Buffalo gage and other gages on the Niagara River. Just what was it your purpose to prove by those charts? What do you understand them to show?

A. Will you specify as to the particular charts you have in mind, Mr. Adcock? Is it the one between Buffalo and the Whirlpool, and Buffalo and the Suspension Bridge; that is a single chart.

Q. Was it the regimen of the river that you attempted to establish there?

A. I think there is only one exhibit, Shenehon's Exhibit H, which is the relative fluctuations of the water surfaces in the Whirlpool and the Gorge Pool plotted with respect to Lake

Erie at Cleveland. Is that the one you have reference to, Mr. Adcock?

Q. Well, there were several charts put in.

A. Shenehon's Exhibit E, is the volume of discharge of the Niagara River related to Whirlpool and Suspension Bridge gages. Shenehon's Exhibit F, of April 15, 1914, is the volume of discharge of the Niagara River related to Suspension Bridge gage. And Shenehon's Exhibit G, volume of discharge of the Niagara River related to the Whirlpool gage.

Q. You had some purpose in mind in offering those exhibits, did you not?

A. Yes.

Q. What I wanted to get was what you considered that they showed?

A. The volume of flow of a river like the Niagara may be referred to the controlling gage at Buffalo, known as the Buffalo gage. It also may be referred to other gages in the river, so that we may write out an equation, a discharge equation, in terms of the height of the water surface at Chippewa gage for instance, or at the Suspension Bridge gage, or at the gage in the Whirlpool; so that we have volume of flow referred to those particular gages.

Then we may, by water level transfer, relate the fluctuations of the Chippewa gage or the Suspension Bridge gage, or the Whirlpool gage, with the gage at Cleveland, the Lake Erie gage at Cleveland; or to the gage at Buffalo. And then by the ratio of fluctuations write out the increment, deriving an increment, first, of course, for these river pools; then write out an increment for the water surface of Lake Erie at Cleveland and Buffalo.

It is a simple, legitimate process of open season transfer of water levels. In the end, the object of this is to answer the criticism made in the testimony as to the Buffalo gage or to the fluctuations of Lake Erie. But these criticisms are that Lake Erie fluctuates so rapidly, and in time of storm the waves may have such an effect on the gage elevations or on the gage pipe, that we doubt the conclusions of that gage. That is the criticism, you understand. But this process is to relate the volume of flow to quiescent places in the river itself where storms do not roughen the water to any large extent, and in this way the Buffalo gage as an element in the derivation of the increment disappears; it is not necessary. When I say that, this relates of course only to the 1907 and 1908 observations, because we did not have these other river gages during the times of the earlier measurements.

Q. How are these gages related to the discharge measurements?

A. The times of the individual discharge measurements are known, and the length of time which it takes to make an observation, so in this process the elevation of the water surface at Suspension Bridge, for instance, was taken at the third even hour after the beginning of the particular discharge observations, and as a rule four of these hourly readings of the gage were taken, taken from these scaled sheets; and then these observations themselves were formed into groups of ten, or in perhaps a few cases there are less than ten in a single one of the groups. The sheets themselves show that.

Then these are plotted with respect to the gage concerned, the volume of flow as shown by the measurements related to the height of the water surface, and the line is computed indicating the law of relationship. From that an increment is derived for this particular pool, for instance the Gorge at Suspension Bridge. And then by this relation of fluctuations between Lake Erie and the particular pool, as the Gorge, we have a multiplier in the relative movement of the Gorge Pool to convert the increment there to the increment referred to Lake Erie at Cleveland, or at Buffalo.

I did not explain the difference in these curves. I believe Shenehon's Exhibit E, took the discharges on days when there are four discharges, and in that case I believe that the ten hour period was utilized, beginning I think at ten o'clock in the morning; in other words endeavoring to put a lag of about 3 hours between the measurement and the water surface elevation in the Gorge. And the same for the Whirlpool. I believe in that case, there were ten even hours taken from these Lake Survey gage sheets for the four measurements of the day, and only those days where four measurements were taken were utilized in making this curve.

This curve, however, was succeeded by the other curves mentioned, where all of the observations available for 1907 and 1908 were utilized in groups of ten, in order of stage.

Q. Why do you use four hours there, Mr. Shenehon? You spoke of the fact that the gage was read for a period of four hours, hourly?

A. Well, we took the nearest four hours after making a time correction, you understand, of three hours. The lag is a little over three hours; so we used the nearest, the third hour after the time of beginning discharge measurement and then the three succeeding hours, including four hourly readings in all to cover the 3-hour period.

Q. Did your gagings last for a period of four hours?

A. Not as a rule. They lasted two hours and possibly a little over. We sometimes took four in a day. That would indicate possibly a little better speed than two hours.

Q. That is you would travel across the river on your gagings taking the observations at various stations, would you?

A. Yes.

Q. And what would you do, take the mean of the four hours to determine the elevation for the period, for your discharge measurements made?

A. Yes.

Q. Did you make any calculations for the time that you were making observations at stations in mid-stream where the percentage of—

A. You mean weighting the mid-stream?

Q. Yes?

A. No, that would not be applicable for a gage so far downstream, I think, or not necessary. The weighting of observations in that way, in the end, is a refinement that tends to reduce the residual a little bit, make the observations a little more accordant among themselves, and has no substantial effect on the final result. That seemed to be a logical, proper method—

Q. There are about 340 discharge measurements made there, aren't there?

A. That is in the Niagara River, we have 219 at the International Bridge in this case and 121 at the Open Section; and 10 at the Split Section, which are not included in the 340 mentioned.

Q. Did the lake remain fairly constant during the period of each of these discharge measurements?

A. That is a matter of record.

Q. It was probably fluctuating during the four hours, wasn't it?

A. Some flunctuations, yes.

Q. And there were certain spans of the International Bridge there where the largest percentage of the water flowed, weren't there?

A. Yes.

Q. You did not make any observations or refer the discharges obtained for those particular spans where the percentage of the water going through was greatest to the elevation of the lake at that particular time, as I understand it, at the time the observations were made at those stations?

A. You are referring now to these reductions for the Gorge and Suspension Bridge?

Q. No, I am referring to the measurements made at the International Bridge?

A. Oh, yes, in the measurements made at the International Bridge where they were referred to the Buffalo gage, they took account of the elevation of the gage at the particular time the station was occupied.

Q. That is at the instant, or for a time before that, eight minutes?

A. In the case of the Open Section that correction was made, and I had an impression it was in the Bridge Section; and I am inclined to think it was in the later observations. But I notice in the 1900 report a statement that it was not considered at the Bridge Section, that ten minute to eight minute lag.

Q. Then as I understand it, at the time you observed at a certain station, you would connect with that observation the elevation of the lake at that particular time, at the time you made the observation?

A. Or with a time preceding by eight to ten minutes.

Q. But you don't know now whether you made any allowance for the time interval on the measurements at the International Bridge?

A. It states in the 1900 report that the observations at the Bridge Section did not take into account this eight or ten minutes lag. In the Open Section it did, but, as I say, in the reduction of the 1907-'08 observations, it is my impression that the lag was taken into account.

Q. You want to state it as a fact that the lag was taken into account in the 1907 and 1908 observations?

A. I state it as my belief. I could not state it as a positive fact.

Q. Did Mr. Moore make those observations, or did you?

A. Mr. Moore made those observations.

Q. You think he introduced that refinement into the observations?

A. It had been rather a customary practice beginning, I think with the—I rather think that was begun in observing the St. Marys River.

Q. When was that done?

A. That was in the Nineties, 1895, 1896.

Q. You overlooked that in your 1898, 1899 and 1901 measurements?

A. On the Niagara?

Q. Yes?

A. I reached Buffalo in July, 1898, and took charge for two months of the office of the Deep Waterways Board of Engineers, and at that time the observations had been in progress for some time, and they were continued for a couple of months by Mr. C. B. Stewart and from that time until July—

Q. I am referring to the Lake Survey measurements that you had charge of on the Niagara River.

A. The Lake Survey measurements began in September, 1898, under my direction and charge, and immediate supervision; and continued until July, 1900.

Q. I just wondered why you did not take into consideration the time interval there, Mr. Shenehon? You state that in the St. Marys River measurements in 1895, that that time interval was taken into consideration, and I understand that those measurements were made by the Lake Survey in the St. Marys River. Did you consider it—

A. We had another thing in the St. Marys River, that was not repeated. That is we corrected for reservoir effect in those earlier measurements, and that appeared to be a refinement that was not necessary, not warranted, and was not used in any of the later observations that I am aware of. This eight or ten minutes is not a very essential thing, Mr. Adcock.

Q. I wondered why Mr. Moore differed with you. You understand that he saw fit to use the time interval there?

A. You mean in his 1907 and '08 measurements?

Q. Yes?

A. He would have my full approval, and I presume it was discussed with me, his doing that on the Bridge Section in 1907 and '08. It would be very natural that the 1907 and '08 work coming later should utilize that correction.

Q. Then your opinion changed as to the propriety of making allowance for the time interval between the early observations—

A. My opinion is now it is a logical, proper thing to do; that in the final result it has very little bearing on either the volume of flow or the increment.

Q. And that was a matter of judgment which you exercised in 1898, when you started in on these measurements for the Lake Survey on the Niagara River, and your judgment has not changed?

A. No.

Q. Notwithstanding the fact that Mr. Moore cited that to you, that refinement in his measurements?

A. No, I should have O. K.'d and possibly I did O. K. his doing that.

Q. Now, after you took these observations, referred the observations which you made at a particular station to the elevation of the lake at that time, or as Mr. Moore did eight minutes before, the Buffalo Gage, what happened to the observations? That is, so far as those particular things were concerned, did you make allowance for the amount of water passing through each station and weight the observations according to that?

A. Now you are getting at this point that some stations, for instance, have ten per cent. of the flow and some have one per cent. of the flow; the gage that prevails during the time of one per cent of the flow, that is the actuating cause of that flow, is given the weight of one. The gage prevailing, the height of the Lake prevailing during the measurement of that station which is ten per cent. of the flow is given a weight of ten. I am making this rather arbitrary, these weights. That is what you have in mind.

Q. Yes, assuming those were the facts. Upon these charts, and in the information that has been presented here in this case, you have an elevation given and the discharge of the lake according to that elevation, have you not?

A. Yes.

Q. Is the elevation given the mean for the four hour period which you mentioned?

A. You are referring now to the Whirlpool and the Gorge?

Q. No, to the International Bridge. What is that elevation that is shown, how do you get the elevation?

A. It is a weighted mean. We find out that in each station there is a certain percentage of flow.

Q. I am speaking of the elevation now?

A. Yes, I understand. I am showing how we get the weight. As I stated before, these stations, one may have a weight of one, another two, another five, another seven, another ten. As we proceed with reference to our Buffalo gage, the gage height that corresponds to the time of the observation, where the weight was ten, was given a weight of ten. It is the weight of the elevation.

Q. That is the particular station?

A. Yes, and the gage elevation is a weighted mean. But whether we had taken a simple mean for the time of the ob-

servation or had taken a weighted mean, in the final result, would have made no difference.

Q. Then you went to a lot of work for nothing, didn't you?

A. It seemed a logical, proper thing to do. Sometimes you do things that possibly have a limit, too much refinement in them. Sabin, I believe, did not weight in the same way.

Q. He took the simple mean, the actual mean?

A. That is my recollection.

Q. His judgment in that connection differed from yours?

A. Not in any substantial measure, not widely.

Q. Perhaps he was trying to follow the path of least resistence, not putting himself to any unnecessary burden, is that the idea? You say it didn't make any difference whether they were weighted or not?

A. I say it made no substantial difference. I had already explained it would probably reduce the residuals a little bit; that is the individual observations would be a little bit more accordant.

Q. Does the fact that you used that method in your discharge measurements of the Niagara River induce you to say that they are better than the St. Clair measurements?

A. No.

Q. That does not have anything to do with the determination of that question?

A. Not any. But I am not certain that you have heard me say that the Niagara River measurements are better than the St. Clair River measurements. I say we were able to get an increment that is determinate and reliable for the Niagara River, where we have a margin of variation in the St. Clair. I have stated in my testimony that I believe the volume of flow of the St. Clair is—

Q. I am speaking with reference to the elevation of the lake.

A. The determination of an increment, of course, is another matter. They had some gage difficulties on the St. Clair that we did not have on the Niagara.

Q. What I was trying to get at was whether the fact you used the method which you have just described had anything to do with your forming an opinion as to the relative accuracy of the discharge measurements?

A. No, I should say it had no bearing whatever on the increments nor on the volume of flow, taken as a total.

Q. Then if you were going to make discharge measurements again for the purpose of determining an increment, or endeavoring to determine an increment, you would not

use the method that Mr. Moore used, or that you used in the Niagara discharges, the weighting and so forth?

A. Yes, I think I would.

Q. Notwithstanding the fact that in your opinion it would not make any difference?

A. There is an advantage in lowering your residuals a little bit; you have your observations in line a little bit better.

Q. What did Mr. Richmond do in his measurements at the Split Section?

A. I believe he did not so weight his gage. I think I would agree with him on that, on account of the distance from the Buffalo gage.

Q. What did you do on the St. Lawrence River?

A. On the St. Lawrence River, we weighted them I believe, although it is a distance there that makes it of rather doubtful propriety. Possibly it was following out a scheme that had been used before.

Q. The distance was greater on the St. Lawrence than it was at the Split Section?

A. Yes, the justification on the St. Lawrence would be less than on the Split Section, for that.

You understand this is a very trivial thing; whether you do it or not make little difference in the final result.

Q. You spoke of the St. Lawrence measurements which you considered threw some doubt on the increment which you had obtained for the St. Lawrence period. Would you just explain what that error was that crept in?

A. I don't know.

Q. You don't know?

A. Mr. Richmond made some observations that appeared to indicate that the water was accelerating at a fairly rapid rate as it crossed the section; and that if our meter was a little further up or downstream it made some little difference, and he appeared to feel that was the reason why there seemed to be this discrepancy between the increments, that seemed by the later measurements less than the earlier increment.

Q. When you testified the other day, you took all the indications which you thought appeared in the later observations and gave the increment which resulted from that?

A. Yes. My testimony on the increment of the St. Lawrence is simply a reflection of the testimony of the Lake Survey men in this case, their independent investigation. It is, as I stated, however, indicated by an investigation through fluctuations, that the increment is between eighteen and nine-

teen thousand; and while this is a crude method, as I stated before, it has influenced my judgment to a certain extent. The relationship between Erie and Ontario is very much better than that between Michigan and Huron and Erie, and there is a reason for that.

Q. Then you are not convinced that the increment which was given as 21,000 for the St. Lawrence River is really the true increment?

A. Not ultimately, no.

Q. You would not want to be understood as staking your professional reputation in this case upon the fact that 21,000 is a true increment?

A. No, my testimony on that must have all the reservations of the witnesses of the Lake Survey on that point.

Q. Then you assume that the opinion given by Mr. Richmond and Mr. Moore, as to the increment being 21,000 may not be the correct opinion?

A. Yes, I think that is subject to a variation of 10 to 15 per cent. either way.

Q. Either way?

A. Yes.

Q. It might be as low as 18,000 or as high as 24,000?

A. Yes, and the indications of the fluctuations would be that it is closer to the down side, although I do not think that is ultimate.

Q. And the increment which you gave in 1909 for the St. Lawrence River in this case was 50 per cent., might be 50 per cent. in error, might it not?

A. No. Let me figure it for you. On U. S. Exhibit Number 2, the increment of the St. Lawrence for the time prior to the building of the Gut Dam, and referred to the gage at Ogdensburg is 28,900. Correcting by 5½ per cent. for the building of the Gut Dam and 2 per cent. to transfer to the Oswego gage gives an increment of 26,870. Then my statement was at that time this might be 10 per cent. in error. Subtracting that gives an increment of 24,180, which is a proper deduction from my earlier testimony. Now I say that the increment may be 21,000 or 22,000, I believe my testimony was.

Q. It might be 18,000, about?

A. I hardly think it is as small as that, probably not smaller than 20,000.

Q. Then your statement that it might be ten or fifteen per cent. either way is not entirely correct?

A. That is a little bit rough, I should say.

Q. Did you make a correction in Exhibit 2, for the Gut Dam?

A. It is noted, yes, both the correction for the Gut Dam and for the Oswego gage. Both those are made in the form of a note.

Q. You said that the period for a change of discharge to pass from the Buffalo gage to the Chippewa gage was two hours for a distance of 20 miles; and from Buffalo to Suspension Bridge, three hours for a distance of 22 or 23 miles. Why, in your judgment, does it take an hour for the effect to travel the last two or three miles?

A. I think the statement for Chippewa is a little over two hours, and the statement for the Suspension Bridge gage is a little over three hours, about three hours and a quarter as I recollect it. That makes an hour's difference. The travel of the water over the rapids, about three-quarters of a mile of the cataract rapids, of course, is very slow.

Q. Is it slower than it is in the river?

A. Doutbless; it is a function of the depth under those circumstances, the travel of an increment of that kind; then the accumulation of water in this Gorge Pool, and the distance I believe from Chippewa is from three to four miles instead of two, as you stated.

Q. What is the cross-section of the river over the rapids?

A. Which rapids? That is somewhat variable. At the head of the rapids, my recollection is it is about three quarters of a mile wide or a little more.

Q. What is the depth, mean depth?

A. May I see the Preservation of Niagara Falls Report? (Referring to same.) Well, the depths pretty well down towards the first cascades from Plate Number 12 on the Report of the Preservation of Niagara Falls are all the way from two and a half, two, three, five and four-tenths, three, four and four-tenths, six and six-tenths, six and six-tenths, six and six-tenths, five and three-tenths, eight and four-tenths, seven and eight-tenths. And on a line across from Chippewa to the entrance of the Hydraulic Power Company's canal, the depths range from 2.3 down to 11.6. The bulk of the way it is less than 9 feet.

Q. How would the velocity there compare with the velocity at the International Bridge?

A. It would be inversely as the depth; that is the shallower water and the width, of course, taken into account; for equal width that would be.

Q. Would the water get through that section faster than

it would through Sections like the International Bridge, or the Split Section or the Open Section?

A. The velocity is faster, yes.

Q. Then it does not take the water longer to get through?

A. The general formula for the travel of a crest or increase in depth going down the river is as the square root of the depth, so the greater the depth, of course, the more rapidly the wave advances. In great depths, of course, they go at pretty high speed; the change of condition.

Q. Are you speaking of the passage of a wave; the change of discharge or change of elevation?

A. Both. I think we have the same condition on the St. Lawrence, the passing of the water over the Galops Rapids.

Q. In connection with the gage readings at the Suspension Bridge and the Whirlpool, were there any measurements of discharge made at those points?

A. At the Suspension Bridge?

Q. Yes?

A. Or the Whirlpool?

Q. Yes.

A. There were no velocity measurements made.

Q. You mean no discharge measurements. By velocity measurements. you mean discharge measurements?

A. I mean at the head of the Whirlpool Rapids, which is the foot of the Gorge, there were no velocity measurements made in connection with the gage reading at the Suspension Bridge gage. The measurements of velocity were made at the International Bridge in 1907-'08.

Q. That was the only place was it, Mr. Shenehon?

A. Yes, in those years.

Q. Then if the measurements heretofore considered in this case are in error as indicated by the testimony of Defendant's witnesses, the indication of these charts would also be similarly in error, would they not?

A. You are referring now to these exhibits that have to do with the Suspension Bridge and Whirlpool gages?

Q. Yes.

A. So far as the volumetric part of the observations is concerned; but the object of these exhibits was to indicate that we could eliminate the Buffalo gage and not regard that as an element of error in the observations.

Q. You wanted to predict the gage height at some other point, passing from the Buffalo gage, is that the object?

A. No, we can predict that from the Cleveland gage, as is done in one of these exhibits.

Q. How closely?

A. Mr. Williams' evidence is full of the closest—

Q. I am asking you.

A. I refer to that, because there are some figures given there which are pertinent, and I haven't in mind the exact coincidence. It is shown on the exhibit, if we can get it, an exhibit that has Chippewa indicated.

Q. I am asking you generally how closely as to time, etc., and as to stage?

A. Monthly mean elevations of the two water surfaces were utilized in the transfer from Cleveland, during the open season, of course, and preferably during the quieter summer months.

Q. That would not have anything to do with your discharge measurements, would it?

A. The relation of two water surfaces, such as the surface of Lake Erie and the surface of the water in the Whirlpool for instance, or in the Gorge, taken over a certain period of time, is fixed; they are very definitely related.

Q. Take the Cleveland gage, say for instance you had a daily reading mean daily Cleveland gage, could you predict from that mean daily a daily mean for the Chippewa gage?

A. Oh, no.

Q. It only relates to monthly?

A. You must take, I should say, as long a time as a month to have any good results, but you can from the Buffalo gage, from day to day, you can predict the Chippewa gage with great precision.

Q. Can you predict the Chippewa gage by hourly readings at Buffalo?

A. Not with the same precision. No, there are some fairly wide divergencies in hours. They will not exactly track.

Q. With reference to what length of time, what period of time would you think it necessary to cover that, in order to predict the Chippewa gage?

A. I should say three or four hours would possibly give a reasonably close relationship. I wish to state in regard to the Chippewa gage that that gage is subject to some fluctuations due to the water in the power canals at Niagara Falls, so the relationship there is not quite as good, taking in a short period like a few hours, as it would be in a day; and of course in a month it is more accurate.

Q. Suppose you had a rise at Buffalo, sudden rise within a half an hour of a half a foot, could you predict what the elevation of the Chippewa gage would be from that?

A. A rise of a foot in half an hour, is that the point?

Q. Yes.

A. No, I should not attempt to predict the elevation.

Q. Suppose you had a rise of a half a foot in an hour?

A. No, I should not attempt to predict very accurately. When I say that, that is within an inch of the elevation of the Chippewa gage. I am not sure but what I could within an inch.

Q. Within an inch?

A. Yes, I think so.

Q. What proportion of the change at the Buffalo gage is the corresponding change at Chippewa?

A. A foot at Buffalo is followed by .56 of a foot.

Q. That is 56 per cent.?

A. 56 per cent.

Q. I show you some exhibits that were introduced in this case, showing the hourly records of the Buffalo and Chippewa gages for November 1st to 6th, 1906, referring to Williams' Exhibit Cross Examination Number 4, two sheets, what hour do you find the first maximum on the Buffalo gage, and what is it?

A. One minute: Has this to do with the lag between Chippewa—

Q. I don't know yet. I am asking you the question. We will use it for whatever purpose we can.

A. The reason I ask you that is that I have tabulations in which the lags are taken out consecutively with a determination that I think has more accuracy than any little picking of these hours might have in this cross-examination. I would be very glad to put those in evidence.

Q. I am asking you, Mr. Shenehon, the question. I will endeavor to use the testimony in the best way possible.

A. The question is to find the crest on the first day, is it?

Q. Yes?

A. Is this confined to the first day?

Q. Confined to the first day.

A. I find that during the whole day, the change of elevation of the water surface at Chippewa is only three-fourths of an inch, and it is very difficult under those circumstances to pick out a crest.

Q. I am asking you as to the Buffalo gage, Mr. Shenehon?

A. This is the Chippewa gage, I had before me. (Referring to another exhibit.) The first crest I find is on the

third hour, a rise of .06 of a foot or three-quarters of an inch.

Q. That is 3:00 A. M., isn't it?

A. That is 3:00 A. M.

Q. The elevation is what, 571.92?

A. 571.92.

Q. How much of a change in one hour?

A. From the hour before?

Q. Yes?

A. 5/8th of an inch, .05 of a foot.

Q. But it is .06 down, isn't it?

A. Yes, on the fourth hour it goes down to .06, or 3/4ths of an inch.

Q. Do you find a corresponding summit at Chippewa?

A. At Chippewa between the third and the fourth hours, we have a rise of .02 of a foot, and it runs level between the fourth and the fifth, and between the fifth and the sixth it shows a rise of 1/8th of an inch.

Q. How long after?

A. That is the next hour.

Q. The next hour?

A. Yes.

Q. You would not consider that that rise had anything to do with the summit that you just spoke of at 3:00 A. M.

A. I think we are getting down to rather little quantities to look for duplication of a crest.

Q. What do you find as to that, Mr. Shenehon?

A. I can read these off.

Q. No, I am asking you if you find a summit at Chippewa to correspond with the summit which you just mentioned as occurring in the third hour?

A. No, not a well marked crest.

Q. What and when is the following low point on the Buffalo gage?

A. The 12th hour, we have an elevation of 571.72.

Q. Do you find a corresponding minimum at Chippewa for that?

A. We have 562.39 for the 14th hour, which is a little below the readings of the hours preceding. The 12th hour is 2.42, the 13th 2.40. This is 2.39, a drop of 3/8th of an inch in the three hours readings there.

Q. For what hour is that?

A. That is down to 14, at the 14th hour; figuring on a two hour lag, we have 2.39. The 15th hour it gets down to 2.38.

Q. What per cent. is that of—
A. Of the change at Buffalo?
Q. Change at Buffalo?
A. At Buffalo, between the 11th and 12th hours it drops down to 0.05 of a foot, and at Chippewa between the 13th and the 14th hours it drops down 0.01 of a foot. That is 20 per cent.
Q. You ought to have predicted that about 56 per cent.?
A. No, I don't think any one of us would have predicted that with these little movements. The effect of the power companies would doubteless be in excess of the quantities at Chippewa indicated here.
Q. When and what is the following summit at Buffalo?
A. We have 1.96 at the 19th hour.
Q. 1.96 what?
A. That is 571.96, 571 is not indicated.
Q. What is the rise from that depression, previous depression?
A. That is .14 of a foot—no, .24 of a foot.
Q. Do you find a corresponding summit at Chippewa?
A. On the 20th hour we have 562.41 which is .03 of a foot over the 15th hour, which was 562.38.
Q. Do you consider that a summit to correspond with the summit at Buffalo?
A. Well, that 15 hours there, that 2.38 is the low corresponding to 1.72, I should say, 571.72 at Buffalo, and the 21 and the 22 hours are 562.42, each of them.
Q. Isn't there a summit on the Chippewa gage?
A. The last observation at 24 o'clock shows 562.44.
Q. What does it show between two and three A. M. of the second day?
A. That goes up to 562.45.
Q. Isn't that the highest following the summit of the Buffalo gage that you just referred to of .24 of a foot?
A. Yes.
Q. What is the interval there?
A. Well, I think these quantities are such that we can hardly take off intervals.
Q. Well, there was a summit at Buffalo wasn't there?
A. I might say that a little more draft in the power house, at the Ontario Power Company, a little more draft in the Niagara Falls Power Company's plant, a little more or less in the Hydraulic Power Company's plant would have a much wider effect than that indicated by the whole range of the Chippewa gage.

Q. Would the draft of these power companies be the same?

A. I think if you are looking for crests you are pursuing an improper method. Or if you are looking for time intervals, you are not pursuing a proper method.

Q. Would a draft on the power house create a summit at Chippewa?

A. A lessened draft.

Q. I thought you said a draft?

A. I suppose we can think of those as plus and minus.

Q. Change of draft?

A. A change of draft, perhaps that is a better statement.

Q. As a matter of fact there is a seven hour interval between the crest at Buffalo where the depression was .24 of a foot and the summit at Chippewa.

A. No, I see no evidence of that fact.

Q. Isn't it a fact that the highest is 7 hours?

A. I state very positively that the pettiness, the littleness of the quantities you are dealing with here are sufficient to obscure the object, if we are looking for the lag.

Q. I am asking you, Mr. Shenehon, as to—

A. That is my answer.

Q. I am asking you as to what those gage readings show at Buffalo and Chippewa?

A. I say that the movement there is reaching the limits of observation and the physical indication is not a conclusion that may be drawn as to the lag.

Q. Then you would not want to take those figures or those records of observations of the elevations at the Buffalo gage and Chippewa as indicating anything that appears on those exhibits. Is that right?

A. I regard this as an improper method of attempting to get the lag out of these little changes in gage elevations, just as I regard the method of getting an increment out of 0.03 foot range on the St. Clair River in the same category.

Q. I am asking you what appears from these exhibits?

A. I am endeavoring to give you as accurate an answer as is possible under the circumstances. You are endeavoring to get a statement as to what the lag is. I say it is not to be gotten out of that day's record.

Q. So that you could not tell anything about the lag from the exhibits I have just shown you?

A. There is nothing determinate as to the lag in that little change indicated on that sheet.

Q. But as a matter of fact the interval of time between

the summit that you have just referred to at the Buffalo gage, seven to eight P. M. of the first day, and two to three A. M. of the second day is seven hours, isn't it?

A. I do not dignify those by the term summits.

Q. They have the highest record, highest gage readings there, the highest elevation shown by that exhibit for that day?

A. We have on the Buffalo gage at the 19th and 20th hours 571.96 and we have on the Chippewa gage the highest elevations, 562.45, on the second and third hours of the following days.

Q. Now there are seven hours between that, aren't there?

A. Yes.

Q. Twenty-four one hundredths of a foot, is how many inches? About four inches, isn't it, three inches?

A. Yes, a little less than three inches.

Q. And you do not consider that that is a change of elevation that amounts to anything?

A. No, I do not state that.

Q. I misunderstood you then. You said it was a trivial, insignificant, small change that would not be indicated anywhere, could not be taken into consideration.

A. I am speaking of your crests at Chippewa now, what you call a crest at Chippewa.

Q. Yes, and we are speaking of a change of elevation at the Buffalo gage in Lake Erie.

A. Yes.

Q. What change of elevation—

A. I have explained also, but perhaps I ought to go into that a little more in detail, that the Niagara Falls Power Companies are lowering the water at Chippewa by a considerable amount, in the neighborhood of four inches; and the change of draft on those plants is sufficient to account for some little irregularities in the Chippewa gage. When it comes to the matter of daily draft, they are so nearly uniform that you may make the prediction with considerable certainty.

Q. What would you consider to be a sufficient raising or lowering of Lake Erie to have any effect or be of any material consequence, so far as this is concerned, determining the same?

A. Whenever Lake Erie goes up one-tenth of a foot, approximately 2,200 cubic feet of water would go down the river. If it is a case of rise, a portion of that will be absorbed in

the reservoir effect as it goes down, and in the end there will be a reflection at Chippewa, but part of that may go through the turbines. It is not necessary to have all of it go through the turbines, and where water is going through the turbines you have a diversion effect that lowers the water; just as the Chicago Drainage Canal lowers the lakes, so we have that condition coming in there.

Q. Well, that rise of .24 of a foot would have some effect on the discharge at the International Bridge, wouldn't it?

A. Yes.

Q. And it would have its full effect in eight minutes?

A. Yes.

Q. It would not make any difference in the discharge at the International Bridge whether that rise had continued down through the river, would it, in your opinion, the full length, so that the river had established its regimen according to the change of stage?

A. You do not understand me to state that a little rise on Lake Erie is going to be indicated for instance in the Gorge by any large rise there, especially if that rise is followed by a fall, do you?

Q. I don't know. I am trying to find out about it. I am looking for information.

A. I stated I would be very glad indeed to present some computations of lag, some tabulations, if you are really looking for that.

Q. We are trying to ascertain just what the travel is there according to these—

A. I can help you very materially if you will permit me to present certain tables.

Q. —according to these sheets which you have presented. I am asking you for those. Now, take the next, what is the change at Chippewa from the last minimum?

A. The last minimum being the 21st hour at Buffalo of the first day.

Q. The last minimum at Chippewa was on the 17th I think.

A. What is your question, Mr. Adcock?

Q. What is the change at Chippewa from the last minimum?

A. Will you state the hour to which you refer, the 21st hour of the first day on the Buffalo gage?

Q. No, I am speaking of the Chippewa gage.

A. The minimum preceding the last maximum.

Q. Yes?

A. The minimum at the 17th hour of the first day.

Q. Yes. What is the change?

A. From what?

Q. From the maximum, from the minimum to the maximum?

A. The maximum I see above there is 562.43. That would be .05 of a foot, 5/8ths of an inch.

Q. Is that the maximum?

A. Yes, I think so.

Q. What happened the next hour, does the gage go down or go up?

A. The minimum as stated is on the 15th hour; goes up one hundredth the next hour and goes down one hundredth the next hour, that is the 17th and goes up one hundredth the next hour; and on the 19th it goes up another hundredth. The 20th is 562.41, the 21st is 562.42.

Q. What is the change?

A. The 22nd is 562.42, the 23rd 562.42, and the 24th is 562.44.

The first hour of the second day of the month,—that is the month of November, 1906—is 562.44; the second hour is 562.45. It continues—I mentioned that before—the third hour 562.45; there is .07 of a rise there.

Q. Seven hundredths of a rise?

A. Yes.

Q. What is 56 per cent. of the Buffalo gage, when do you start on the Buffalo gage?

A. The Buffalo change on the first day of the month is from 571.72 to 571.96 on the 19th hour. That was .24. Is there a question?

Q. Yes, what is 56 per cent. of the Buffalo change?

A. That would be about .13.

Q. Then the observation at Chippewa was five hours late and about 50 per cent. too small, wasn't it?

A. According to the indication of these other changes, yes.

Q. When and what was the following minimum at Buffalo?

A. On the sixth hour of the second day we have 571.72.

Q. What was the change from the last to maximum?

A. That would be the same thing that we had before, a drop of .24.

Q. Do you find a corresponding minimum at Chippewa?

A. On the 8th hour we have 562.38 which is a drop of .07 from the maximum preceding.

Q. When and what is the following summit at Buffalo? In that last, by reason of the fact that Chippewa did not change to correspond, is there another change of draft on the power house?

A. I will not attempt to explain the difference.

Q. You gave that as something that probably happened with reference to the other—

A. We are working with rather a short base here.

Q. We will take another one; we will get a little larger base. When and what is the following summit at Buffalo? Look at 15 o'clock. 572, wasn't it?

A. The following summit?

Q. Yes?

A. The 11th hour on the second day 1.93.

Q. Summit at Buffalo?

A. Yes, 571.93 on the 11th hour of the second day.

Q. What is the corresponding change at Chippewa?

A. There is a rise of 0.01 by the 13th hour and .02 by the 14th, and the highest is shown on the 18th, 572.43.

Q. How long after is that?

A. Seven hours.

Q. Won't you have to find another summit there about two hours previous for the Buffalo gage?

A. I think we are working on a rather short base here.

Q. We are trying to find a larger base. We are trying to get these intervals as they show on that exhibit. How much was the change from the preceding minimum on the Chippewa gage?

A. .05.

Q. That happened at 18 o'clock, didn't it?

A. 18 o'clock.

Q. Look for three hours previous at the Buffalo gage, what do you find? You find 572, don't you?

A. Yes, 572.00.

Q. And the change from the preceding minimum on the Buffalo gage is .28 of a foot, isn't it?

A. .28, yes.

Q. Would it be your opinion that the summit at 18 o'clock on the Chippewa gage corresponded to the summit at 15 o'clock on the Buffalo gage?

A. I should prefer to get better marked changes, in order to work out this lag.

Q. .28 of a foot is a little over 3 inches, isn't it?

A. Yes. Of course, we have a range, you know, on the Buffalo gage of 4 feet.

Q. Do you think there is another draft on the power house there, from the power house?

A. I am very positive that the draft for this power is going on very constantly, and I presume there are some fluctuations.

Q. What percentage of the total flow is the draft?

A. Somewhere in the neighborhood of 20,000 cubic second feet at the present time.

Q. About ten per cent.?

A. Yes.

Q. How much of a change would you anticipate there might be, or variations from this?

A. The lowering due to that is somewhere in the neighborhood of five or six inches. I am not quite certain as to that.

Q. How much is the change of draft variation in the flow?

A. I can't give you that; I haven't the power curves of the company. The Niagara Falls Company has a light and traction load, and some little variation in the load. The Ontario Company I believe also furnished power for light and traction on the American side.

Q. On what do you base your statement as to the change of draft?

A. General knowledge of power companies.

Q. But you don't know what the variation of flow is?

A. No.

Q. You don't know whether there is any variation at all as a matter of fact?

A. Yes, I know as a matter of fact there is.

Q. You know the percentage of 24-hour power these people consumed, don't you?

A. I think it is all sold as 24-hour power, or practically all; and yet when I say that I am not certain as to the Ontario Power Company load.

Q. Do you know the load factor?

A. No; I know the Hydraulic Power Company's is pretty nearly the 100 per cent. factor, so the variation is rather small.

Q. According to that, the change at Chippewa was one hour late and about 70 per cent. too small, wasn't it?

A. Well, it was late and small.

Q. 70 per cent.?

A. Some large percentage. I don't remember.

Q. You think that might be because of the change of draft in the Power Company?

A. I state that as one of the uncertainties, and I am—

Q. We will take the next. When is the next minimum at Buffalo? Look at 21 o'clock, elevation 571.78.

A. 21 o'clock?

Q. Yes.

A. 571.78.

Q. What is the change?

A. From the 572 above is .22.

Q. Do you find a corresponding minimum at Chippewa? When you look for a corresponding minimum, what time interval do you take there?

A. I look for about two hours. The drop is .04 between the 18th hour, the last summit at Chippewa, and the elevation is 562.39.

Q. There is about four hours there on the Chippewa gage where it was absolutely steady, wasn't it, following that summit?

A. Yes, there are five hours.

Q. Five hours there wasn't any change?

A. No.

Q. So you do not find any depression to correspond to the almost three-inch change at the Buffalo gage?

A. There is no well marked corresponding change.

Q. If you were plotting that, you would have a straight line, practically for that?

A. The five hours.

Q. For five huors would be a straight line, horizontal line?

A. Yes.

Q. When is the next summit at Buffalo? Look at 2 A. M. the third day.

A. On the third day at two o'clock we have 572.04.

Q. Is there a corresponding summit at Chippewa?

A. Yes, the gage rises a few hundredths; on the fourth hour it is 562.43, a rise of .04.

Q. It remained stationary there for about four hours?

A. It runs stationary for four hours.

Q. If you plotted it, you would have a horizontal line, wouldn't you for four hours?

A. Yes.

Q. And the change at Buffalo is a little over three inches, isn't it?

A. Yes, one-eighth of an inch over three inches.

Q. When is the next depression at Buffalo?

A. On the eighth hour we have 571.74, a drop of .3 of a foot.

Q. That is about eight o'clock, isn't it?

A. Yes, that is eight o'clock.

Q. From seven to eleven, it runs practically steady?

A. Well, we have a drop between the peak at the seventh hour there at Chippewa, we run down to—

Q. I am speaking of the Buffalo gage?

A. Yes, that runs steady, pretty nearly steady for four hours there.

Q. That is a pretty good length of time?

A. Yes.

Q. And the change was very near four inches, wasn't it?

A. Between that and the 572.04 recorded above?

Q. Yes?

A. Yes.

Q. Where does this appear at Chippewa, at what time, if at all?

A. Chippewa shows a drop down to 572.36 by the 12th hour, from 572.43.

Q. Isn't it the 13th hour?

A. It runs down to .34 on the 13th. That is the minimum, 562.34.

Q. It stays pretty regularly there from 13 o'clock to 16 o'clock, doesn't it?

A. Yes, it is fairly steady there.

Q. How much is the change at Chippewa?

A. The drop was .07 of a foot.

Q. What would be 56 per cent. of the Buffalo change?

A. About .17 of a foot.

Q. The actual was .07, wasn't it?

A. Yes.

Q. So—

A. I think there is one thing I ought to call your attention to as we—

Q. You may be asked that on re-direct. What was the interval, six hours about?

A. It is a little difficult to tell where these are so flat in both the Buffalo gage and the other one.

Q. This was approximately four inches, the change?

A. It runs pretty flat down for several hours, as you mentioned in your question, five hours there we haven't well defined peaks there.

Q. There is a change from Buffalo of pretty near four inches, isn't there from the—

A. Less than four inches.

Q. A little less?

A. Yes.

Q. Nearer four than three inches?

A. About 3⅝ths to be accurate.

Q. It is .295 of a foot, isn't it? What was the interval there?

A. These observations are of such a nature that it is very difficult to determine the interval. Sharp, well marked peaks are necessary to determine an interval. These are running flat here for five or six hours.

Q. Now, you have here at seven o'clock, the depression commenced at Buffalo, did it not, and it remained that way until about 11 A. M.

A. It would appear to me, Mr. Adcock, that these observations speak for themselves. I do not see any crest on a level running along here at Buffalo, 571.75, .74, .75, .74. I must confess my determination of a lag would hardly depend on any such series of observations as you are picking out.

Q. The gage was falling, was it not, and it ceased to fall at a certain time and remained practically stationary for four hours at Buffalo?

A. A limitation should be placed upon this, where the movement is so little, that these are hourly scalings, and there may be a variation at Buffalo, there may a little valley between the hourly readings, and this form of determination would hardly follow. When you get a well marked peak, then it is different.

Q. It fell four inches in about three hours, didn't it?

A. Between the second hour and the seventh hour and the third we have a fall of—

Q. Fell pretty steadily, pretty fast?

A. Nearly .3 of a foot.

Q. How much quicker would you want it to fall in order to have it show, indicated at Chippewa?

A. Well, I would be very glad to present the tables which will show—

Q. I ask you now from these gage readings to tell.

A. I would suggest, moreover, that we have the readings

plotted in the three-curve series, in which Buffalo and the Whirlpool are indicated and the lag indicated between—also the Gorge, that the lag indicated between the Gorge and Buffalo must be greater than the lag between Chippewa and the Lake, and it is a clear inference, there is a large well marked movement there, with no water power complications, and there the interval is about three hours and fifteen minutes.

Mr. Adcock: I will move now to strike out the witness' answer to the question, and ask the reporter to read the question; see if the witness will answer the question asked.

Mr. Hopkins: I object to the general line of inquiry. I have not made any objection, but this is simply asking him to state the contents of a document which is already in evidence, in the first place, and making computations on matters inquired into on the witness stand. And the third reason is he has testified it does not give any results because of the very small range in the limitations, among other things, that makes it of no value.

Mr. Adcock. I assume counsel supposes there is not anything to be considered in this case but the witness' opinion. We have the right to cross-examine the witness upon the facts about which he has testified concerning gage readings. He has presented himself as Chief Expert for the Government. I do not think it comes with very good grace from the Government to try and limit the cross-examination of its Chief Expert. Now read the question.

(Question read as follows: "How much quicker would you want it to fall in order to have it show, indicated at Chippewa?")

A. I should like to see changes in the neighborhood of a foot at Buffalo, and with reasonable sharpness of crest so as to accent the influence well. We have in our exhibits what is known as the Three-Curve Series, which gives rather conclusive results. It has been testified to by—

Q. How quickly do you want that change to take place at Buffalo?

A. Oh, in three or four hours.

Q. That would be rather unusual, wouldn't it?

A. Yes.

Q. I understood you to say so a little while ago?

A. Yes, and yet we can find cases where this change is accomplished.

Q. There would not be a great many of those, would there?

A. The Three Curve Series is illuminating along this line.

Q. I am asking you the question; am asking how many you can find?

A. I will be glad to refer to these curves. That will make me better able to answer your questions.

Q. How many in a week? How often would that change take place?

A. I would have to refer to curves.

Q. But Mr. Shenehon, you are very familiar with the Niagara River?

A. Yes.

Q. You have written a work here entitled: "The preservation of Niagara Falls," and you examined the river at all points. You are familiar with the stage of the lake as shown by the gages at Cleveland and Buffalo, the fluctuations, and I assumed that you would be able to give us an idea of how often you would find a change of 1 foot in three hours at the Buffalo gage?

A. Have you any objection to my referring to the documents in this case?

Q. You have the right to refer to them, certainly. I am asking you for the information.

A. (Examining exhibits.) I examine sheet number 1, of Shenehon's Exhibit K, in which the water surface elevation of Lake Erie at the Buffalo gage is shown from October 21, to November 8, in the year 1907. I find one case where the change in the elevation of Lake Erie was 1 foot in about seven hours. That is, the rise and fall is accomplished in that length of time.

Q. That is the Three Curve Series, Mr. Shenehon, is it?

A. Yes, sheet number 1, of the Three Curve Series.

Q. And that is the only change, only instance where the change—

A. No, there are cases where the lake has either lowered or raised substantially a foot in four or five hours.

Q. How substantially, what percentage of a foot?

A. There is one about .9 on the 24th.

Q. In how long?

A. In about five hours, and the fall on the following day is accomplished, a foot in probably the same length of time. On the 25th, there is a rise of nearly a foot in about six hours.

Q. What percentage of a foot?

A. It is pretty close to a foot. We can call it roundly a foot.

Q. But minus?

A. That is rising; on the falling—on the down drop there is a foot fall, a little bit over a foot accomplished in about eight hours.

Q. You only find on that Three Curve Series there one instance that really meets your conditions, as a matter of fact?

A. No, on November 2nd, I find that the lake rose nearly two feet in the time, about five hours?

Q. What year is that?

A. That is the year 1907. And I find well marked peaks corresponding to these on the lower curve of this sheet, showing elevations in the Gorge of the Niagara River.

Q. Have you got the Chippewa gage on that?

A. No, the Chippewa gage is not plotted on this.

Q. Did you get the relation of the Chippewa gage from those observations?

A. The lag in the Chippewa gage was gotten out by my assistant, Mr. Souther, from the gage sheets.

Q. What gage sheets?

A. Similar to the sheets that you put in my hands here for inspection.

Q. But those are the ones which you presented to Mr. Williams on cross-examination, are they not?

A. Yes.

Q. Why did you take others?

A. I rather think these are among the sheets that we utilized. The Lake Survey Office has been open to Mr. Williams, and all its records, so far as that is concerned, to choose any other particular sheets.

Q. What did you use to determine this lag, or the relation of Chippewa to 56 per cent. of the Buffalo change?

A. In that determination, the daily mean elevations of the Buffalo gage and the Chippewa gage were used and computed, not for one year alone, but for at least two, and the results are printed in the report on the Preservation of Niagara Falls.

I may add also that in this same river pool, across the river from Chippewa on the American side, what is known as the Grass Island gage gives substantially the same amount. This thing is so well established that one year's result checked within 1/8th of an inch of another year.

Q. How then did you determine the lag from the daily means to be two hours? How could you introduce that refinement into the daily mean observations?

A. The lag was determined from the hourly gage sheet.

Q. Just as we are trying to do here. That is what I asked you first, Mr. Shenehon, as to how you determined the lag?

A. Well, the method used by you is the proper method, except that you should select days where there is a fairly large movement instead of these days of smaller movement.

Q. Have you got the plottings by which you determined the lag in the hourly mean of hourly readings?

A. I find two sheets here on which the lag is determined both for rising and falling water, July, 1908, and November, 1907. I rather think there are some more; and the results on these surprise me a little. They appear to have been in error. The mean lag for July, 1908, in well marked high water is 2.6 hours. That is between the Buffalo gage and the Chippewa gage, and the well marked low water lag is 2.55, or two hours and 33 minutes.

Q. What are your well marked low water and high water and so on there?

A. The days are given on these sheets.

Q. Is that hourly readings?

A. These are from hourly readings, the hour from which a well marked low point is indicated at Buffalo is set down and also that at Chippewa, and the difference is taken out and these are summed up and the mean taken out.

Q. What are you referring to, the exhibits in this case?

A. This is not an exhibit at this time. I rather think I have some more of these Chippewa sheets. I think in this derivation of the lag at Chippewa, we found the same difficulty that you gentlemen are discovering to-day; and that an inference from the lag determined at the Whirlpool is probably better value than attempting to get it out of Chippewa.

Q. You considered it was necessary in order to determine the relation of the Chippewa gage to the Buffalo gage to take the daily mean?

A. Yes.

Q. Did you ever take a daily mean discharge measurement of the Niagara River?

A. No.

Q. Never did?

A. You mean continuous 24 hour measurement?

Q. Yes?

A. No.

Q. You never took a discharge measurement of the Niagara River when the gage at Buffalo and the gage at Chippewa for 24 hours were at equilibrium, did you?

A. We took 340 observations, and during this period we may safely assume that the normal relations existed between Lake Erie and the elevation of the water at Chippewa, and that sometimes at Chippewa it was a little too low, and sometimes it was a little too high, and therefore we have these residuals to which I have referred. That is one discharge measurement shows a little to the right of the line, indicating it is a little too big; another one a little to the left, showing it is too small, and these are the errors of observation that are present in all work, all the best work as well as other kinds.

Q. And you have given your judgment as to what percentage the error is, all those things?

A. Yes. Understand me that the residual, the final error in the result coming in from the elevation of the water at Chippewa, is in my judgment, zero, in other words it is an effect that is entirely compensated in the result.

Q. Mr. Shenehon, in testifying with reference to lag, you referred to two papers here, which you have just kindly allowed me to look at, entitled: "U. S. v. Sanitary District of Chicago, determination of lag between Buffalo and Chippewa gages, time required for change in Lake Erie to reach Chippewa. Only days of well marked changes used in determination." There are two sheets, and they cover the period where there are apparently some gage readings that were made in 1907 and some others in 1908 used. You have columns there; a column where you say "lag hours" "comparison with Buffalo and Chippewa." I see cases where the lag is 4.5 hours; others where it is 5 hours; others where it is 1 hour; others where it is intermediate; one 5 1/2, another where it is zero, 3.5 hours, 5 1/2, and another one at zero; various estimates put down as to lag. How do you account for those discrepancies?

A. The water movement is very small at Chippewa compared to Lake Erie.

Q. How did you then reach the conclusion that it was 2.6 hours?

A. By averaging, summing them up, average.

Q. You took a number of these different gage readings from Buffalo and Chippewa, etc., and used your judgment about picking them out?

A. No, I didn't use my judgment. I put it in the hands of a very capable assistant.

Q. And he used his judgment?

A. He used his judgment.

Q. And then to get the time interval you took an average of all these?

A. Yes.

Q. Including the zero?

A. Yes.

Q. And the one hour, and everything else?

A. Yes.

Q. And upon that you are willing to make the statement that the lag there is 2.6 hours?

A. It appears from that particular table. I don't mean to state that as an ultimate conclusion. I wish to put in the lag as derived on well marked gages in the Gorge where the movement of the water is 2.29 that of Lake Erie, where it is well determined, where there is no water power complication, no large water power complication entering.

Q. Two per cent. you say?

A. 2.29 is the ratio of movement between the water in the Gorge at the Suspension Bridge gage, and Lake Erie.

Q. Before making any statement—

A. It seems to be a certain thing that the lag at Chippewa is less than the lag at the Suspension Bridge, because the water must pass over the rapids after it leaves Chippewa, a travel of three or four miles.

Q. Then before you would like to leave this case with the statement that the lag there is 2.6 hours, you would want to make further investigation, wouldn't you?

A. Yes. I recollect now that in our earlier measurements —I had forgotten it, and this is not very clear yet in my recollection, either—that we did have a time interval of two hours and forty minutes; and I don't know how I got it in my mind recently that it was two hours.

Q. There isn't anything else you think you would like to study more carefully before you want your opinion to go into the record?

A. Yes. I am going to give you the statement of the lag at the Suspension Bridge through the Whirlpool.

Q. Are there any other opinions you have given in this case that you feel you would like to make further study concerning the basis of the opinion, the method of arriving at it?

A. You mean correctly figured.

Q. No, method of correctly arriving at the results. You

say here you do not want to stand by your opinion as to the 2.6 hours.

A. I had an impression that the lag was about two hours. I think that was my earlier statement, and I wish to fortify or confirm my error, if it is more than two hours. I had not in mind these tables that I have here, and I think there are other tables of the Chippewa gage that may not be quite in accordance with these.

Q. You will look them up in the meantime will you, and if you have any papers from which you determined this lag, you will bring them so that we can examine them?

A. Yes. Of course in the end, you must understand that the lag is very clearly shown between Buffalo and the Gorge Pool which is four miles below Chippewa roundly, by the Three Curve Series. It is there for inspection, and may be made out by anyone concerned, and it is not necessary to take this—

Q. Mr. Shenehon, we will no doubt reach that famous Three Curve Series in due time; but I am concerned about this lag.

A. You were asking for my assistance, weren't you?

Q. Yes.

A. In reaching a really accurate conclusion that will be helpful to the court in this matter.

Q. That is right.

A. That is what I am attempting to give you.

Q. And I hope we may have an opportunity to look at the figures or papers by which you refresh your recollection as to the determination of the lag.

A. I shall give you the best knowledge I have, I assure you, in that and every respect.

Adjourned to Wednesday May 14, 10:00 A. M.

Wednesday May 14, 1914, 10:00 A. M.

FRANCIS C. SHENEHON, resumed the stand and testified further on cross-examination as follows:

Mr. Adcock: Q. Have you got any of those sheets this morning that you mentioned you had last night?

A. I haven't any more sheets than the two I had last night.

Q. That is with reference to the lag?

A. I have sheets concerning the lag in the Gorge, at the

Suspension Bridge gage and in the Whirlpool, which are pertinent in this discussion.

Q. You haven't any more sheets concerning the lag between Buffalo and Chippewa?

A. Only the two I had last night.

Q. Now, Mr. Shenehon, we were talking about a depression at Buffalo, which occurred about seven o'clock and lasted until 11:00 A. M. on the third of November; and the change from the previous peak was .295 feet. And we also spoke of a depression at Chippewa, which occurred at 13 o'clock and lasted until about 16 o'clock, in which I believe you stated that if you plotted those gage elevations it would be approximately a horizontal line, and the depression at Chippewa, or change, was .07 foot. You also stated that 56 per cent. of the Buffalo change would be .165 feet. Then I asked you as to the interval between the depression at Buffalo and the depression at Chippewa, which apparently would be six hours. Is that correct?

A. This is on the third, you are speaking of now? And on the Buffalo gage it is from the 7th hour to the 11th hour?

Q. Yes?

A. Substantially.

Q. Yes.

A. 13th to the 18th it keeps on going further. The level is so flat there at Chippewa that it is rather difficult to state what the time interval would be.

Q. It would not be less than six hours, would it?

A. I would not attempt from these observations to determine the lag.

Q. What is the change at Chippewa? The marked change is about six hours, isn't it?

A. There does not appear to be any very sharply marked change.

Q. Would it aid you any if we showed you a plotting of that? (Handing witness same.) I will ask the Commissioner to mark for Identification certain blueprints showing plotting of the gage elevations of Chippewa covering November 1st to 6th, inclusive, of the year 1906. These plottings were made from the gage records appearing upon Williams' Exhibit cross-examination number 4, being two sheets presented to Mr. Williams on his cross-examination by the counsel for the Government, and prepared, I believe for such offer by the witness. Mark them Shenehon's Cross-Examination A and B.

Whereupon plottings handed to witness, were marked respectively Shenehon's Cross-Examination A and B.

A. I would like to ask whether or not the Buffalo gage has been corrected for the hourly readings as indicated by the note on Williams' Exhibit Cross-Examination Number 4? I understand Mr. Williams to say that this correction has not been applied.

Q. Would it make any difference in the relative elevation of the Buffalo gage?

A. No, it would make a difference when you come to predict the Chippewa elevation from the Buffalo, to see whether or not my statement was conservative that we could come within an inch in the time of four or five hours in the prediction.

Q. Would it make any difference so far as the plottings are concerned, and the fluctuations at Buffalo?

A. No, so far as the fluctuation of the lag is concerned, it is not pertinent.

Q. It is not pertinent?

A. No.

Q. So the inquiry which you made was also not pertinent, is that right, to the question which is before the court?

A. My inquiry had to do with the general proposition of the relation between the Buffalo and the Chippewa gages.

Q. Yes, but so far as the determination of the lag is concerned, the purpose for which these exhibits were prepared, it would not have any materiality?

A. No. Now, if I can get the question, I will endeavor to answer it.

Q. (Question read as follows): "What is the change at Chippewa? The marked change is about six hours, isn't it?")

A. This relates to the third and has to do with the tenth on the Buffalo gage and the sixteenth hour on the Chippewa? Yes, that appears to be about six hours.

Q. Then the time is three hours and four-tenths late, and 50 per cent. small, basing this upon your correction of last night with reference to the lag, you stating now you believe the lag to be 2.6 hours?

A. Well, I didn't make that as a final statement. I stated that a sheet which was presented indicated that, and my original statement, of course, was that it was two hours and fifteen minutes; and even under that statement it would be about two hours and thirty-four minutes, the mean of these

two columns, the rising and the falling water. The conditions are such at Buffalo that we get a large error of observations.

Q. It would be 50 per cent. small too, wouldn't it, to change at Chippewa?

A. I presume that is an inference from the figures. I don't recall substantially.

Q. When is the following summit at Buffalo, Mr. Shenehon?

A. I am referring now to the blueprint. I assume the blueprint is correct.

Q. Look at 16 o'clock.

A. Well, there is a subordinate summit at 13 o'clock and another one at 16 o'clock on the Buffalo gage on November 3.

Q. The change there is .235 feet?

A. .24, I make it on the Buffalo gage.

Q. Does this appear at Chippewa?

A. There is very little change indicated at Chippewa in this column. There is about .02 indicated at Chippewa.

Q. Which is really insignificant?

A. Insignificant.

Q. And the change at Buffalo was approaching three inches, was it not, very near three inches?

A. Yes.

Q. When is the next minimum at Buffalo?

A. On the fifth hour of the fourth day, November 4th.

Q. Isn't it two to three A. M.?

A. Well, we have a rapidly vibrating condition at the Buffalo gage, where we have evidently a seiche running back and forth, with a range of two or three-tenths within a couple of hours. And I think that really in this discussion we have to take a mean line passing through those seiche points.

Q. What is the lowest point there?

A. The lowest point is on the fifth hour, at five o'clock.

Q. Five o'clock. And what is the change?

A. The difference is .98 of a foot, a little less than a foot.

Q. That is approximately a foot, isn't it?

A. Yes, a quarter of an inch less than a foot.

Q. When does this appear at Chippewa?

A. Two hours later.

Q. What is the amount of the change at Chippewa?

A. .28 of a foot as I make it.

Q. That was a rather gradual change wasn't it at Buffalo?

A. Yes.

Q. It was quite a change too, wasn't it?

A. Yes, that is a well marked change.

Q. What is the per cent. of the Buffalo change at Chippewa?

A. Roundly 28 per cent.

Q. 28 per cent.?

A. Yes.

Q. That is about 50 per cent. small, isn't it?

A. Yes.

Q. Do you think you have really got the depression at Chippewa which corresponds to the Buffalo change?

A. Yes, I think so.

Q. How do you account for its being only 28 per cent.?

A. Error of observation.

Q. Error of observation?

A. Yes.

Q. Then it is something that might be pretty difficult to tell what it is?

A. I am inclined to think if you will take the mean of say four or five hour elevations at Buffalo, and compare them, without picking or selecting your observations with the corresponding elevations at Chippewa, you will find this relation holds within the limits I stated, as a general thing.

Q. You cut it down to minutes, two hours and thirty-four minutes a while ago?

A. I am speaking of the relationship, 56 per cent. relationship in fluctuation. That is a very well determined thing.

Q. How long was it from the time the water began to fall at Buffalo until it began to fall at Chippewa?

A. About five hours is the interval indicated. The Chippewa showing declines about five hours after the change.

Q. That was a steady fall running over quite a little time?

A. Yes.

Q. As shown at Buffalo?

A. And yet on the Chippewa gage you have this flat elevation, level water indicated for five hours there, any point of that may be considered the peak, I suppose, of that particular high.

Q. You would not expect the change at Chippewa to occur in no time at all, would you?

A. No.

Q. That is after a change at Buffalo?

A. No.

Q. That is you would not expect Chippewa to change as the Buffalo gage changed?

A. No.

Q. You would not expect it to change within one hour, would you?

A. I had in mind before two hours, and I have not quite decided where that impression came from. It appears from this sheet it is over two hours.

Q. Would it be reasonable at all for an engineer to expect the change at Chippewa to be within one hour after the change at Buffalo?

A. Oh, yes, it would be reasonable.

Q. It would be reasonable?

A. Yes.

Q. You think you would work it out that way, would you?

A. I think we are still within the limits of reason when we call it one hour.

Q. You certainly would not expect Chippewa to change at the instant Buffalo changed, would you?

A. No, indeed.

Q. Why do you use the zeros here in these—

A. You are touching on a fundamental fact in observational data.

Q. I hadn't quite finished the question. In determining this lag, why did you use the zeros? These sheets that were prepared by Mr. Souther, and which were handed you yesterday entitled: "United States vs. Sanitary District, determination of lag between Buffalo and Chippewa." And then I find on that you state the lag to be zero in three instances on the first sheet, and one hour in several instances, and you say the way that they determined what the lag would be or was, was by taking the mean of those determinations from individual instances?

A I started to say this represents—

Q. Just a minute: Do you think that is a fair thing to do, to take the zeroes there into consideration?

A. I think my explanation must proceed, in answer to a question of that kind. The zero does not represent an ultimate fact. It represents a conclusion with a minus residual. In other words, you will find some of the observations show a lag that is longer by a couple of hours or three hours than the actual lag, and others will show three hours too little. And this is a characteristic thing in all observations. The zero simply means that the error of observation is on the minus

side. If we should eliminate the zero by selecting observations, which is not in my judgment a good practice as a rule, we would also eliminate the 5.5 because it is too big in the same proportion that the other is too small.

Q. Why do you eliminate the minus three hours to which you just referred? Isn't it just as unreasonable to suppose that the change at Chippewa would be at the same instant as the change at Buffalo as that Chippewa would change before Buffalo?

A. If you will understand, the taking off of these things is subject to an error of two or three hours in any particular case, or may be subject to the error, and the error may be too small by two hours or three hours or it may be too big, an even thing. If you take out your zeroes, you must also take out all your large observations. In other words you retain them all. And understand, while this appears to be an inconsistent thing that the time interval is only zero, or nothing, it is also inconsistent that it is 5 1/2 or 6 hours, and these two things balance each other in the final result. That is a well known illustration of the compensating error of observations.

Q. You say it is inconsistent it should be 5 or 6 hours and yet we find numerous instances where the Chippewa change was 5, 6 or 7 hours after the Buffalo change, do we not?

A. In selecting well marked changes, those should be incorporated as a portion of the observations, but you should not select those that are big, and not include also those that are little, unless you have a predecided view as to what you wish your lag to be.

Q. You have just referred to one here where the change was a foot, haven't you quite a well marked change?

A. Yes.

Q. That you speak of?

A. Yes.

Q. I also asked you to look on those exhibits which I handed you and ascertain how long after the Buffalo gage began to fall, the Chippewa gage began to fall, and you stated it was five hours.

A. Yes. That would be a very proper observation to incorporate in here (indicating exhibit). And I point out to you that there are on this sheet one observation in which the lag is shown as 4½ hours, another 5½, still another 5½, another 3½. Now, these observations of 5½, assuming that the lag is about 3 hours, let us assume it is 3 hours, the five hours and a half bear about the same relation on the big side that

the zero does on the small side. One is too big and the other too little, and the average of the two, zero added to 5.5 divided by 2 is 2.75, or 2¾ hours. So the average of those, taking the big and the little ones, gives pretty close to what appears to be the correct result by this computation.

Q. If you were going to eliminate 5.5 hours, you should also eliminate the zero. Is that correct?

A. I would not do either as an observer, understanding some of your quantities would be too big, some too little. I do not feel at all concerned about a zero lag on the one side and 5.5 hours on the other.

Q. So you would eliminate both of them?

A. No, I would eliminate neither. I would leave them both in just as I have done. The elimination of observations is a very dangerous thing.

Q. If you were going to eliminate either one of them at all, which would you eliminate?

A. I would eliminate both in that case. I would get out my mean first, and say this is so big it does not correspond with the mean, and this is so little it does not correspond, so cut them both out.

Q. Which is the more unreasonable, the zero or 5.5 hours?

A. It is about an even thing from the point of view of the observer, understanding how some observations strike too little and some strike too big. It is an entirely reasonable conclusion that an observation may appear to have a zero lag, when the error of observation may be one or two or three hours.

Q. Doesn't one of these waves or crests travel at a regular speed?

A. You mean all of them?

Q. Yes?

A. I think the gage records here indicate considerable concerning that.

Q. As an exact fact, would not two similar changes in elevation travel down to Chippewa in about the same time, within a minute? In other words, if you had two, one change say of a foot—

A. Yes.

Q. And then you could determine exactly how long that took. You had another change of exactly a foot at another time, wouldn't you expect the two to travel in exactly the same time?

A. No.

Q. How much difference?

A. I can't state that. The observations indicate the range was between zero and 5½ hours. And the mean indicates about 2¼ hours there on that particular sheet.

Q. I am asking you as to whether you think there would be certainly any difference in the travel between two exactly the same changes?

A. I am inclined to think for you to get exactly duplicate conditions would be rather difficult.

Q. But if you had those conditions?

A. If we had exactly similar conditions at exactly the same time of year, exactly the same stage of the river, exactly the same state of affairs as to wind and weed growth and other conditions, I should expect one to duplicate the other very closely.

Q. What effect would the weeds have on the current, how much would they detain the travel?

A. Very little.

Q. What per cent.?

A. I could not state it as a percentage.

Q. How many minutes?

A. I could not state it in minutes.

Q. Would it be three minutes?

A. I should say as much as three minutes.

Q. Would it be as much as five minutes?

A. I am not prepared to define it.

Q. Would it be as much as an hour?

A. No.

Q. Half an hour?

A. No, I think not.

Q. Would it be as much as 15 minutes?

Q. You are getting down to pretty fine limits. I am not prepared to say. I should say it would be less than 15 minutes.

Q. It would be less than 15 minutes?

A. Yes, I should say so.

Q. Well, what effect would the wind have?

A. Very little.

Q. What would be the effect from that in minutes?

A. An upstream wind has a little retarding effect, a downstream wind a little accelerating effect, but that is extremely small so we do not need to give that any large consideration in this lag effect.

Q. Would it be less than ten minutes?

A. Yes, I think so.
Q. Might be less than five?
A. I would not like to define it.
Q. Probably less than five?
A. I would not wish to define it any more closely.
Q. What other things might affect the travel of that crest?
A. The elevation.
Q. How much would the elevation affect it?
A. That is the depth of the water. That varies as the square root of the depth. There would be a little change coming in that.
Q. How much, how many minutes?
A. Suppose we had five feet in the one case—
Q. We are taking the ranges here, we are taking one foot. That is a well marked change, which you have reference to.
A. I think I can get at that. I should say five minutes would be an extreme, not over five minutes, I should say.
Q. Is there any other influence?
A. Of course, barometric pressures enter in a slight degree in this.
Q. How much effect would they have?
A. I could not make a statement concerning that.
Q. Would it be an appreciable effect in minutes?
A. It would not be much. Mr. Williams in his testimony indicated between the Buffalo gage and the Section about .05 of a foot, that is in a distance of two to three miles say. In these other distances proportional to that, you would have quite a considerable effect. Of course in the end it is a thing that balances out, just as Mr. Williams, I believe, testified himself, as between the Section and the Buffalo gage. So, while individual observations may show it for a short time, the large number of observations utilized in making a determination would eliminate it in even a small number of hours. I do not conceive of any large barometric change lasting over five hours.
Q. Well, if add altogether, your weeds, your barometric pressure, your winds and everything like that retarding the crest, it would not amount to 20 minutes, would it, the difference?
A. No, I should say not. I don't know that the barometric pressure has a great deal to do with the travel of the crest. I am speaking now of the consistency of the two gages.
Q. You mentioned barometric pressure, and as I do not know anything about it, I assumed that it had something to

do with it. Of course in asking you the question, I want you to take that into consideration.

A. Of course if it passes from one grade to another it must traverse the length of the river. I do not think it is a thing that needs any large consideration.

Q. What is the approximate average depth of the Niagara River from the Buffalo gage to Chippewa?

A. I should say in the neighborhood of 20 feet. I am not positive of that. I would need to take it off from the chart. (Examining same.) I should say 16 might be a fair value, approximate value, 16 feet.

Q. Well, what is it from the Buffalo gage to the Bridge?

A. It is deeper for the most part. The question was from the Buffalo gage to the Bridge?

Q. Yes?

A. I should say a little deeper, probably 20 feet.

Q. You still think do you, Mr. Shenehon, it is just as unreasonable to suppose the lag would be 5.5 hours between Buffalo and Chippewa as to suppose it would be zero?

A. I think you misunderstood me. I say that as an observation, an observation is just as consistent where it shows zero as where it shows 5½, where the mean of a large number of observations, is about 2½ hours.

Q. Why do you take zero into consideration?

A. I simply take zero as an observation in which the error is on the minus side. In other words it is too small, and the other one is too big, and these things balance each other.

Q. But physically, zero is entirely impossible, isn't it?

A. Yes.

Q. Do you say physically 5.5 hours is impossible?

A. No.

Q. Would you say physically 7 hours was impossible?

A. No.

Q. Would you say physically 8 hours was impossible in the lag there?

A. I would not wish to set any particular limits to the lag. I should determine the lag from what the observations indicated on the stream itself. After I had reached a determination, as I have, somewhere in the neighborhood of two or three hours, then I should regard with suspicion a lag of 8 hours or 7 hours in any particular observations.

Q. But, Mr. Shenehon, I am asking you for your opinion as an expert?

A. Yes.

Q. And as an engineer, and I appreciate you have given

great study to this proposition, and I would like to have your opinion as to whether or not you consider 9 hours physically impossible for the lag there?

A. You mean as a final conclusion?

Q. I am asking you for your opinion?

A. As a final conclusion that the lag is eight hours?

Q. No, I am asking you for your opinion as to whether physically it would be impossible for the lag to be eight hours on any observation?

A. I don't know what conditions might be superimposed to bring a lag of eight hours, as great a lag as that.

Q. Then do you say it would be physically impossible for it to be eight hours between Buffalo and Chippewa?

A. In my judgment the lag itself is not eight hours.

Q. It is not what?

A. It is not eight hours.

Q. Would it be impossible for it to be eight hours?

A. In my judgment it is not eight hours, and I don't think in any case in which we showed a clearly marked relationship it would be eight hours.

Q. You have stated that it is physically impossible for the Chippewa gage to change at the same instant as the Buffalo gage?

A. Yes, that is true.

Q. You have also stated it was physically possible for the lag to be one hour, haven't you?

A. It is physically possible?

Q. Yes?

A. Yes, I think it might.

Q. Now I am asking you whether you think it physically possible that the lag would be eight hours?

A. No, I don't think so.

Q. You do not?

A. No.

Q. You would say the same thing with reference to nine hours?

A. I think an observation might show it, but I should regard it as the error of observation.

Q. Would you include such an observation in determining this mean?

A. Yes, I would.

Q. Would you discard a nine hour lag if you had an observation showing it?

A. I might begin to scan the observations, unless they

were so well marked as to be very determinate, if they showed any such lag as that.

Q. Would you discard a minus 1 hour at Chippewa?

A. No, I think not.

Q. A minus two hours?

A. No.

Q. Minus three hours?

A. No, I don't think so.

Q. You would not discard a zero?

A. No.

Q. Although you know it would be physically impossible to have a zero?

A. You are going outside the limits of the error that appears in the observations here, well marked observations.

Q. You have based your increments in the various rivers in this case upon the consideratin of the lag between the controlling gage and the discharge section, haven't you?

A. Not to any large degrees; no, I should say it is almost independent of the lag, so far as the Niagara River is concerned, for instance, and so far as the St. Clair River is concerned. In the St. Lawrence, I think there is a chance that the lag does enter in the original determination of the increment there.

Q. Then I take it you treat it as inconsequential whether the river is in equilibrium at the time your gaging is made. Is that correct?

A. Yes, the observations are taken and recorded as the river is flowing and as the gages indicate, and we have eliminated, so far as I am aware, no observations for conditions where the river may not be in equilibrium.

Q. That is you have eliminated the observations?

A. No, we have not eliminated the observations; we have included them all.

Q. Now, you would include observations which were physically impossible with observations which were physically possible, in determining your average for the lag?

A. You mean this lag determination?

Q. Yes?

A. I would include the zeroes, if that is what you mean.

Q. You would include a minus 2, a minus 3?

A. There appear no minus 2's or minus 3's.

Q. I am asking what you would do?

A. I think I would give the matter some consideration before determining that. I imagine the young man who went through these did not select any where that condition ap-

plied. You will notice the honesty with which he did work, in putting in the zeroes. That is evidence to my mind that he worked with entire honesty in carrying out the task which I gave him: "Now, find out, Souther, what is the lag between these various gages; take these gage sheets, pick out the well marked lows at the Buffalo gage and the well marked lows at the Chippewa gage and the Gorge and the Whirlpool, and set down the time interval, and reach a conclusion."

Q. On these two sheets, you find the mean lag shown at the bottom of the pages, 2.6 hours, 2.55 hours, 3.31 hours?

A. Yes.

Q. 3.5 hours?

A. Yes.

Q. Would you say that the mean of all those was 2.6 hours or was two hours and 34 minutes, or two hours?

A. From those sheets, the mean of the four would be the most probable value, but you will notice these are in pencil and were not regarded as sufficiently determinate to reach a conclusion on the lag. These were never inked in and used. I am not sure whether I have a set that was inked in, or was used. But if the lag indicated here was greater than the lag indicated four miles below in the river, where the thing is well determined and sharp, I should say this was in error, and it is in error just from this difficulty of picking out the highs and the lows with the small range of fluctuation above the falls. That is the point.

Q. What is the mean of all those lags?

A. A little under three hours.

Q. Just three hours minus a little, isn't it?

A. Yes.

Q. Now these sheets were evidently prepared for this case, weren't they, "United States vs. Sanitary District of Chicago, determination of lag"?

A. Yes.

Q. There is a formal heading?

A. Yes. Some others were prepared also.

Q. It bears date September 24th, 1913?

A. They were initiated with a view of use in this case, as we are now using them.

Q. Now after you have taken into consideration the mean of the totals there, would you want to change your answer in any way as to the statement that it would be as unreasonable to expect a lag of 5.5 hours as to expect that there would be no lag at all?

A. Those very nearly balance. I am not going to give

you a final answer on that until I give you the lag as determined at Suspension Bridge, because that is pertinent.

Q. Mr. Shenehon, I am asking you about these gage records appearing in Williams' Exhibit Cross-Examination Number 4, and on these sheets which you have produced entitled, determination of lag between Buffalo and Chippewa.

A. I understand you want my best judgment as to what the lag is.

Q. I am asking you with reference to these observations?

A. The mean value indicated by these sheets is—

Q. Just a minute.

A. —substantially 3 hours.

Q. Do I understand you to say still that a lag of 5½ hours is as questionable as a lag of zero?

A. Practically.

Q. That there would be no lag at all?

Mr. Hopkins: He never said the lag was that, but the observations of lag.

The Witness: I think you understand that, that the observation in a particular case is subject to error, and the error appears to be as large as two or three hours, and when the error is on the negative side, if three hours is the correct lag, zero appears as the observation value.

Q. Will you explain how that record could come in? These records are from automatic recording gages, as I understand. Those gages you have described, and they are a continuous record, the level being shown at every second and minute by means of continuous lines drawn in pencil on a sheet of paper, when the water rises and falls?

A. The small movement of the water at Chippewa is an element in that that I do not find in examining the Suspension Bridge gage, residuals or errors of observation of quite the same magnitude and the fact that with sharp changes—and these are likely to be the kind that are picked out in well marked changes—the full effect is not shown at Chippewa where Lake Erie is rising. There would be a less important effect indicated at Chippewa; where the lake is falling, there would be a lesser fall; that is would be lesser rise and lesser fall; that is sharp, well marked changes.

Q. What is the error of observation of a recording gage?

A. Extremely small.

Q. About one-tenth of 1 per cent.?

A. It is hard to express it in percentages.

Q. Define how it may creep in?

A. Well, the Chippewa gage, as I understand it, was a

gage of the small type, recording on a scale of three inches to the foot. At the point of reverse, there is a chance for a little error of a few hundredths to come in.

Q. Few hundredths of what?

A. .03; .03 or .02 of a foot.

Q. How about time?

A. There is a chance for a little error of time. I think the clocks are so cared for that the error in those little gages is not very big, and yet there has been a time when the slipping of the paper would introduce some little errors. Whether or not they are present in these gages or not, in this particular record or not, I am not certain.

Q. Would it be five minutes?

A. I could not say as to that.

Q. Would it be two hours?

A. Oh, no, I do not think there is any error of that kind that would come in.

Q. Would it be half an hour?

A. I do not think there would be errors of half an hour.

Q. Ten minutes?

A. I don't know that I could define that.

Q. You would not expect it to be ten minutes, would you?

A. No, I should say not. I think the main reason is the small movement that was probably present at the time of these changes.

Q. Now on this sheet entitled "United States vs. Sanitary District, Determination of Lag," etc., you have here well marked high water at Buffalo and at Chippewa?

A. Yes.

Q. What changes were included in those observations?

A. They are indicated by the date shown in the first column.

Q. Just a minute. You don't know what the changes were that are included in those papers referred to, which you produced yesterday, do you? You don't know the amount of the changes at Buffalo?

A. No, from the sheets themselves, one of these is November, 1907. The days on which well marked changes occurred appear, and the dates in the first column, and a reference to the gage at Buffalo for those dates will indicate the change, and the hours themselves are given so it can be determined from this sheet.

Q. When you say "well marked," you don't know whether those are what you would call well marked changes or not, do you, referred to on those sheets?

A. This was an investigation submitted by me to an assistant, and it is dependent upon his conclusion as to what were well marked. I did not very carefully supervise his work.

Q. When you say "well marked," you simply mean that the paper states that they are well marked changes, is that right?

A. Yes.

Q. What instructions did you give Mr. Souther with reference to preparing them?

A. Simply to make a determination of the lag by selecting the well marked changes; where those changes were crests, put those in the one column, and where they were lows or valleys put them in the right hand column, so as to see whether or not when the water was going down we had the same lag as when the water was going up, as a comparison. I must say that it appears that this series is incomplete; that for the Suspension Bridge, the Gorge and the Whirlpool, I used five different sheets, and I appear to have only these two at Chippewa at the present time. My files at Minneapolis doubtless contain other sheets concerning the Chippewa gage.

Q. How large changes did you tell him to take?

A. I didn't give him any definite instructions on that, as I recollect it.

Q. You just left it to his judgment to pick out well marked changes?

A. Yes.

Q. Now proceeding, Mr. Shenehon, when is the next summit at Buffalo?

A. A summit appears on November 5th, at the fourth hour.

Q. At four A. M. on the 5th, the elevation was 572.01, wasn't it?

A. The change appears to be about .99 of a foot between the low for that day and this high.

Q. You would call that a foot change, wouldn't you?

A. It is within one per cent. of a foot, 99 hundredths, as I said.

Q. You were speaking of well marked changes yesterday?

A. Yes, I would regard that as a well marked change.

Q. Do you find this change at Chippewa?

A. The corresponding change appears above five hours afterward.

Q. What was the change?

A. Change from extreme low at Chippewa to high is .28 of a foot.

Q. What is 56 per cent. of the Buffalo change?

A. Practically .56, which is practically half of that.

Q. Half of it?

A. Yes.

Q. 50 per cent., yes, wasn't it?

A. The change is less than it would figure by the 56 per cent, relation, yes.

Q. It is also some hours late according to your proposition, isn't it?

A. It is five hours indicated here.

Q. That is not very far from 5.5, though?

A. At Chippewa the crest does not appear really well marked here.

Q. So it is probable that there is not any crest shown at Chippewa, isn't it, marked crest for the change at Buffalo?

A. When the Buffalo gage went up this little sharp peak and dropped down again, that is not very clearly shown at Chippewa. A real sharp, quick change at Buffalo is not very fully reflected throughout the river, that is at Chippewa.

Q. How long did this change at Buffalo take?

A. It went up about .07 in an hour.

Q. How long did it take to go up the foot?

A. I am in error about that. I must make a correction for that; it went up a foot in eight hours.

Q. Eight hours?

A. Yes, but it dropped very quickly.

Q. How long?

A. In one hour—it went up about one tenth and dropped down again in the second hour following, about one-tenth.

Q. How long was it up?

A. Well, we have a single observation there indicating that high point.

Q. How long did it take it to drop?

A. It reaches another valley or low point in six hours.

Q. I am asking how long it took to drop to the low point?

A. That is what I am trying to give you.

Q. Seven hours?

A. This point here (indicating) six hours.

Q. That was a very rapid change, wasn't it?

A. No, the fall is not very big there. That is a fall of only .3 of a foot in six hours.

Q. What happened at Chippewa?

A. We have a fall of about .01 of a foot there, following that by four hours.

Q. Now when is the next summit at Buffalo?

A. That is on the 16th hour of November 5th.

Q. And what is the change, about .31 of a foot?

A. About .3 of a foot.

Q. That is about four inches, isn't it?

A. A little less than four inches. It is pretty close to four inches.

Q. Does this appear at Chippewa?

A. Yes.

Q. When?

A. Four hours later.

Q. What is the Chippewa change?

A. .04 of a foot.

Q. And 75 per cent. small, wasn't it, based on the 56 per cent. basis?

A. It is a very large percentage small, yes.

Q. And two hours late, according to your statement of the lag between Buffalo and Chippewa?

A. Something over an hour late, yes.

Q. Do you now say that the lag is two hours or three hours?

A. I will give you a statement on that: 111 determinations, individual determinations of the lag at Suspension Bridge have well marked high water—

Q. You have spoken of the Suspension Bridge and the Whirlpool and so on. Just as you go along and make your statement with reference to them, give us the geography.

A. I believe my early testimony does give this, but to review it, what is known as the Suspension Bridge gage is just above the old Suspension Bridge across the Niagara River, the Railroad Bridge at what used to be known as Suspension Bridge, New York. It is just above the head of what is known as the Whirlpool Rapids, and this is below the cataract.

Q. When you speak of the cataract, that is what we commonly call Niagara Falls, isn't it?

A. Yes.

Q. The fall of water over the ledge of rock there?

A. Niagara Falls, of course, consists of the rapids above the cataracts themselves, and the small cascades that come in there. And I suppose it really refers to that whole region, including the rapids and the Whirlpool.

Q. I am speaking of what the sight-seers see when they go to see the Falls.

A. The Cataract is a well recognized name applied to these particular large falls of water which you have reference to. This Suspension Bridge Gage records the elevations and fluctuations of the water in this Gorge, this big still pool that is sunk down 200 feet below the general level of the country there. And the gage, as I have said, is near the head of the Whirlpool Rapids, where the water makes a descent to the Whirlpool. Then the Whirlpool gage is in the Whirlpool itself, which is that circular basin at the foot of the Whirlpool Rapids and at the head of what is known as the Lower Rapids; and in each of these pools the fluctuation of the water is very large for a change of a 1 foot at Buffalo. Of course the fluctuation is caused by the added water sent down by the additional foot at Buffalo, and the rise in the Gorge pool and in the Whirlpool. Now, this big range of stage there makes these changes very well marked indeed, so that it is fairly easy to pick them out and get excellent determinations. And at the Suspension Bridge Gage, this determination is for the months of October and November, 1907, June, July and August, 1908. The days selected were those when there was well marked change, and in the various months—

Q. What were the changes at Buffalo?

A. Those will appear on the Three Point Series of curves.

Q. I am asking you what were they?

A. It is not set down in the tables. They are well marked changes.

Q. That Three Curve Series, or Three Point Series, is it—

A. That will show the particular hours.

Q. You discussed that yesterday, didn't you?

A. Yes, I mentioned it yesterday.

Q. All right.

A. Now, during the month of October, there were 23 days utilized. During the month of November there were 23 days; during the month of June, 21 days and during the month of July 23, and during the month of August 21, making 111 different determinations of the lag. And the mean for marked high water is three hours and six minutes. This is three to four miles below Chippewa. The mean for a well marked low water is three hours and 18 minutes. The Whirlpool is still another mile or so down the stream, and there the mean of 113 observation or determinations shows a lag of three hours and nine minutes. That is for well marked high water, and for well marked low water, three hours and 26 minutes.

Now it goes without saying, I think, that the lag at Chippewa must be less than the lag at either of these places, so that it, in my judgment, is well determined that the lag at Chippewa is less than three hours.

Q. It is minus three hours?

A. It is three hours, and that earlier relation that I spoke of yesterday that came, I think, in the determination back in 1903, as I recollect it now, is two hours and 40 minutes. I have an impression that was mentioned in this report on the Preservation of Niagara Falls. I am not sure whether it is. So, that is not far from the truth as I see it.

Q. About three hours?

A. Two hours and 40 minutes.

Q. In other words, in the three or four miles, you think it would take about 40 minutes to make the travel, do you?

A. Yes, we have a different condition coming in there, the passage of the water over the Rapids, the sheer fall.

Q. You made the statement in your direct examination here that the lag between the Buffalo gage and Chippewa was two hours, and I believe also other witnesses, Mr. Moore and Mr. Richmond and Mr. Ray made the statement that the lag between Buffalo and Chippewa was two hours. Do you now wish to correct your testimony with reference to that, if you made such a statement, and do you now consider that Mr. Moore and Mr. Ray and Mr. Richmond were in error when they made that statement in their examination?

A. I think my statement was somewhere in the neighborhood of two hours and fifteen minutes.

Q. Well then, do you wish—

A. You understand that now with the absence of or in completion of the observations at Chippewa—I have only a partial record here, and my recollection is that it was somewhere in the neighborhood of two hours and fifteen minutes.

Q. That was your statement that the lag was?

A. Yes.

Q. Now do you wish to correct that statement?

A. I think it is somewhere between two hours and 15 minutes and two hours and 40 minutes.

Q. You gave the minimum then didn't you?

A. In my earlier testimony?

Q. Yes?

A. I have an impression that was based on something, and possibly it is the other sheets of this series that helped me to form an opinion. It may have been it was formed from conclusions from these sheets I have just quoted.

Q. You don't want to be understood now as giving any opinion as to what the lag is between Buffalo and Chippewa?

A. You mean definitely, down to ten minutes?

Q. No.

A. Yes, you can put me down definitely as saying not to exceed two hours and 40 minutes, and possibly as little as two hours and 15 minutes.

Q. When you made the statement it was two hours, or two hours and 15 minutes, you did not want to be understood as stating it was an exact—

A. Oh, no.

Q. An exact fact?

A. Oh no, this matter of lag is subject to a little variation.

Q. As a matter of fact you don't think now, do you, that you have made a sufficient study so that you can give a definite opinion as to what that lag is?

A. Not within 10 minutes. I would not wish to be tied to the nearest ten minutes.

Q. How about the Lake Survey witnesses, do you think they have made any further study than you have made?

A. I am not aware of what they have done. Mr. Moore has done considerable work on the Niagara River, and they have later gage records that have not been consulted by me.

Q. You don't think they have gone any further than you have with reference to these investigations?

A. They have later records and have made reductions of them but I should not expect them to change that very much outside the limits I have given.

Q. Two hours and 15 minutes?

A. Between that and two hours and 40 minutes.

Q. If you were asked the question as to what the lag was, you would not give the minimum would you, two hours and 15 minutes?

A. It would depend upon the purpose of the statement.

Q. Of the examination. If I asked you now what the lag was between Buffalo and Chippewa, you would not say it was two hours and 15 minutes, you would not give me the minimum, would you?

A. I think the fairest kind of statement would be to give you the range, yes.

Q. I take it you will inform the Lake Survey of this error, or perhaps failure to make complete investigation with reference to that, so that they will not put this matter in any of the reports of the Chief of Engineers, won't you?

A. Well, I might seek further illumination myself as to the lag as they have determined it. I think we have the lag very well determined indeed for the Gorge and for the Whirlpool. That I think is an excellent determination, over 100 points.

Q. When is the next depression at Buffalo?

A. We have a depression at Buffalo on the 21st hour on November 5; and it is continuous for about four hours with a little jag in between.

Q. What is the change?

A. The drop from the prior summit or peak is .28 of a foot.

Q. That is about three inches and a half?

A. 3⅜ inches.

Q. Close to three inches and a half?

A. Yes.

Q. Wasn't that drop from 572.01 to 572.04?

A. That is wrong; I am wrong about that. The scale doubles up here. It is .36 of a foot.

Q. .36 of a foot?

A. Yes.

Q. When does that appear at Chippewa?

A. It appears at Chippewa at the third hour of the next day.

Q. What is the time?

A. As a mean for that whole depression there, it would be about four hours later; five is a better value.

Q. Five hours. What was the change at Chippewa?

A. .06 of a foot.

Q. How much low, about 80 per cent., wasn't it?

A. Yes, very much low. I will give you that more exact; 70 per cent. low.

Q. 70 per cent. That is it is 70 per cent. less than it should have been according to the 56 per cent. determination?

A. Yes, of course the 56 per cent. is not applicable to these changes of this particular kind.

Q. I see. We understand, I think, your position on that, Mr. Shenehon. That is that you should have determined it from daily changes.

A. Yes, a portion of the rise at Buffalo is absorbed in the reservoir effect of the river.

Q. And extra draft, you haven't forgotten that extra draft from the power house. That is another thing.

A. That is a thing that is compensating, and is just as likely to be one way as another, and in an individual case it

may distort the thing in daily means; on a large number of observations it eliminates it. I do not think that is a very large thing anyway, that variation.

Q. And it was about an hour and 45 minutes late too, wasn't it, that change?

A. Yes.

Q. According to your minimum?

A. A little more than that I guess.

Q. An hour and 15 minutes, according to your maximum?

A. I think I stated a difference of five hours, wasn't it?

Q. Two hours and 20 minutes.

A. Yes, you ought to get the full value of these things in.

Q. What is the next summit at Buffalo? That .37 of a foot change there at Buffalo was something over four inches, wasn't it?

A. .36, yes it is a little over 4¼ inches.

Q. 4¼?

A. Yes. The next summit at Buffalo, the well marked peak is on the 10th hour of November 6, and shows a rise at Buffalo of .36 of a foot.

Q. That is a little over four inches too, isn't it?

A. Yes, same as you had before.

Q. Do you find this at Chippewa?

A. This peak at Buffalo is a fairly flat one, because there are little variations of tenths or so and there are several hours approximately the same elevation, within a tenth or two of the same elevation, so that I should judge there would be about a two hour difference there. As a matter of fact, if you should take that extreme peak at Buffalo and the starting of the peak at Chippewa, we would have zero difference. It would be better to take, say, the center of those two groups and that would indicate about two hours—it would be about four hours.

Q. About four hours?

A. Yes.

Q. What was the change at Chippewa, what per cent. of the change at Buffalo?

A. Let me correct that last statement. That would be a little over three hours. The question was the rise at Chippewa.

Q. Yes, how much?

A. .05 of a foot.

Q. What per cent. of the change at Buffalo?

A. 75 per cent.; does not conform with the 56 per cent.

relationship within 75 per cent.

Q. Within 75 per cent.?

A. Yes. I would expect that.

Q. You would expect it?

A. Oh yes.

Q. What is the next depression at Buffalo?

A. There is a depression which is indicated at its minimum at the 14th hour. The lake drops .24 of a foot.

Q. That is an even three inches, isn't it?

A. Yes, a little less than three inches, and we have .03 drop at Chippewa coming about two hours later.

Q. What is the per cent. of the Buffalo change?

A. It is about 25 per cent., in error 75 per cent., if it should be assumed that the 56 per cent. relationship would hold, which of course we would not assume in a case of this kind.

Q. Now Mr. Shenehon, when we started to-day here to ask you about the depressions at Buffalo and the summits at Buffalo, compared with the summits at Chippewa and the depressions at Chippewa, you protested about our going into it didn't you because you didn't think it would have any value in the determination of the lag, but we have at least done this: We have caused you to make an examination of your papers, and go over the records here with reference to those gage readings, so that you think that perhaps your opinion as to the lag was incorrect, as given in the re-direct examination. Is that correct?

A. It was rather roundly stated as two hours and fifteen minutes. I am not sure I did not use two hours; I rather think I did.

Q. You did?

A. Yes, it was a round statement.

Q. Do you remember whether you said approximately two hours?

A. No.

Q. What is the Chezy formula?

A. It is a formula for the flow of water in open channels.

Q. What is it?

A. Velocity equals C times the square root of RS.

Q. I notice you give that very readily. It is a formula that every engineer should know, every hydraulic engineer should know?

A. I presume a great many hydraulic engineers do not carry in their minds formulae. I carry very few myself.

Q. Isn't that one usually carried by hydraulic engineers?

A. It is like the fundamental formula for the velocity of water issuing from an orifice, or in general—

Q. You imagine that it might be a good deal like the maxim of the law that persons must come into equity with clean hands?

A. Yes, I have heard that.

Q. You heard the testimony of Mr. Hayford in this case didn't you?

A. Yes.

Q. In fact you assisted him in the preparation of his testimony, didn't you?

A. Well, I do not think it goes quite to the point of assistance. I placed in his hands certain documents and explained what they were.

Q. You told him what you wanted to prove by him, didn't you?

A. What investigations he should make.

Q. That is the ultimate facts which you wished to arrive at?

A. Yes. Investigate the precision of the work from all points of view.

Q. And after he had made that investigation, you went over the results of his investigations with him, didn't you?

A. On the occasion of his testimony.

Q. That is before he testified?

A. I do not think in detail. I did know his results prior to his testimony.

Q. And you knew the general results, didn't you?

A. No, I do not think that I knew until his testimony.

Q. When you say detail—you said you didn't know the detail?

A. Yes.

Q. What did you mean by that? Now you say you did not know anything about what he would testify to before he went on the stand?

A. I believe I had gathered the impression, and I am not sure just how, that his determination was that the observations were precise. But the exact figures I did not know.

Q. Did you know anything about his determinations with reference to the percentage of error, various percentages of error that he mentioned there in his direct testimony?

A. I do not quite understand that.

Q. For instance, the percentage, the error that might result from the rating of the meters or from the velocity, weeds, turbulence, and things like that?

A. Now the question, what is the form of the question?

Q. (Question read as follows): "Did you know anything about his determinations with reference to the percentage of error, various percentages of error that he mentioned there in his direct examination"?

A. No, not prior to his testimony, I had not gone over those in detail with him.

Q. But you knew that he had reached a conclusion as to the precision of the work?

A. Yes, I knew his views of conclusions as to the precision, prior to his testifying.

Mr. Hopkins: I enter a general objection to this, as not cross-examination.

Mr. Adcock: Q. Do you recall his explanation of the criticism of the Three Point Method, wherein he said (page 2730 typewritten record; printed record 3102, 3103, and 3104) "In other words, if you interchanged the discharge and let the elevations stand, in your computation, the final result of the computation from the Three Point Method will be unchanged," do you remember that?

A. Yes, I remember he discussed that. I do not remember the exact wording.

Q. You remember the substance?

A. Yes.

Q. What I have stated is the substance?

A. I think so.

Q. If such a transposition were made, would the observations then fall approximately in a straight line with the rest?

A. I do not know; I have not given full consideration to the case cited.

Q. You have understood, have you not, that in the use of the Three Point Method by the Defendant's witnesses in this case, it has been restricted to the discussion of observations which did fall approximately in a straight line?

A. No, I do not think that to be a fact.

Q. I take it you understand that the St. Clair observations of discharge and elevation and so forth, and the St. Lawrence River observations do not fall in approximately a straight line?

A. No, that is not a conclusion to be drawn from my statement.

Q. You got the application of the Three Point Method, did you not?

A. If Mr. Williams will plot the groups that he chose for the Niagara River—

Q. I am speaking of the St. Lawrence and St. Clair, Mr. Shenehon. Perhaps Mr. Williams did not consider the Niagara observations were worth plotting?

A. Yes, I think he reached a premature conclusion of that kind. I have in mind also the case of the relations of the lakes. If you will plot those lines, they do not come in very accordant straight lines. For instance the relation between Michigan-Huron and Erie and the—

Q. I am not asking you that.

A. If those were plotted, the observations used by Mr. Williams, they will not fall in very accordant straight lines; but the Three Point Method was used in reaching a conclusion, reaching not only one conclusion but two conclusions as to the relationship.

Q. With reference to the observations of discharge, how did you do that, for those two rivers?

A. The method used by Mr. Williams in his chronological period scheme threw the observations off from the straight line. In other words the relationship between the lake and the flow was aggravated, made to fall further from a straight line.

Q. Did you plot those to determine whether they fell in a straight line?

A. I plotted Niagara, and there we have the case of observations that to start with fall in very accordant straight lines, as indicated by Shenehon's Exhibits B and D.

Q. I am asking you about the St. Clair and St. Lawrence Rivers?

A. No, I did not plot those.

Q. So you do not know whether they fell within a reasonably straight line or not, do you? Is that true?

A. Well, from the methods used—

Q. I refer you, Mr. Shenehon, to Plate 6, of Williams Exhibit 34, with reference to the St. Lawrence River and ask you to look at that and state whether that refreshes your recollection with reference—

A. The six groups plotted on that chart appear to line up fairly well in a straight line. I refer to Plate 5, in which eleven groups of the St. Clair River are plotted and the observations are extremely discrepant, do not fall on the straight line.

Q. They are affected by the level of Lake St. Clair, aren't they?

A. Plates 6 and 5, differ, so far as I recollect it, in the fact that one is of one set of years—no, plate 6, is of the St.

Lawrence River. There, there was not very much variation, according to the method used by Mr. Williams.

Q. Plate 5, what is that?

A. Plate 5, is the St. Clair.

Q. That was with reference to the elevation of Lake Huron, wasn't it?

A. Yes, and yet my recollection is that those are corrected for the backwater effect of Lake St. Clair. This I think is the final increment of Mr. Williams regarded as his best increment, 28,872.

Q. What proportion of the discharge of Lake Erie is due to the local supply on the average?

A. Do you mean the amount that is contributed by its watershed and by the rain falling on the lake less the evaporation? In my statement concerning that, I took the run-off as computed by Mr. Gardner S. Williams over a term of 16 years; assuming a mean rainfall for those 16 years, or a rainfall corresponding to that shown in Table LIXa, I think, of Williams' Exhibit 34. That represented something like 7,400 cubic second feet as the yield of the watershed, during the months June to November inclusive.

Q. Did you agree with Mr. Williams on his determination in that regard?

A. I had made no determination of the run-off myself, for the reason that it appears to me good. There are two reasons; one is Mr. Williams attacks the thing in the proper manner, that is making an investigation of so much of the stream flow of the watersheds themselves as was available, and the other reason is that when you utilize Mr. Williams' figures, it puts in accord the flow of the St. Clair River, the Detroit River and the Niagara River. And when you utilize either Mr. Williams' figures or Mr. Stearns' for Ontario, it puts the St. Lawrence in accord very closely, within two or three per cent.; two per cent. I think it is, with the Niagara.

Q. What proportion of the annual discharge of Lake Erie is due to the local supply, on the average?

A. Mr. Williams' figures indicate .66 of a cubic foot per second per square mile of drainage basin. When you come to the full year, the analysis is complicated, and in the end unsatisfactory, unless you make a correction for the ice conditions in the St. Clair River.

Q. Now Mr. Shenehon, I am not asking you for an analysis of the testimony of the witnesses in this case. I am asking you to assume from your experience, and give us an opinion as to what you believe to be the proportion of the annual dis-

charge of Lake Erie that is due to the local supply on the average?

A. My answer is: The best evidence I have, as to what it is is the testimony as to run-off given by Mr. Gardner S. Williams. I have never made any independent investigations.

Q. You never made any attempt to ascertain what that was, independently?

A. No. That is true.

Q. And when you determined the increments for these various outlets of the lakes, you did not think it necessary to determine that question, is that right?

A. No, I did not.

Q. You were willing to rely entirely upon your observations made with the current meter used by the Lake Survey. Is that true?

A. Don't understand me to say that I do not regard an investigation of that kind as desirable. I think it should be extended to include the rivers that Mr. Williams did not include in his examination.

It was a missing link in the physics of the Great Lakes; and it had been surmised and guessed at or estimated before; and Mr. Williams' method of attack is the one that should lead to the best methods. Of course his method is subject to considerable percentage of error, so far as that is concerned.

Q. Do you think it is as desirable to use some method of that kind in determining a correct increment as it is to determine the lag or to use the eight minute interval between the Buffalo gage and the International Bridge?

A. Well, I don't see any relation between that and the derivation of the increment.

Q. I know, but when you give your opinion as to what an increment is, you would like to know whether that increment is correct; you would like to test it, make various tests, wouldn't you to determine that question?

A. Yes, the tests that we applied on the Niagara, for instance, were duplicate sections, the increment being substantially the same in each; and it was tested by referring the measurements to the gage in the Gorge.

Q. Also at Chippewa, wasn't it?

A. And also at Chippewa, yes.

Q. You were willing to rely upon simply those tests, the agreement between the Open Section and the International Bridge Section, were you?

A. Yes, and yet when you open up the whole line of the rivers and the individual supply, that is additionally valuable

and I do not wish to discount that in the least. It is proper to test mean volume of flow.

Q. What is the percentage of the discharge of Lake Erie due to local supply on the average, the annual discharge?

A. In answering that question, I might assume the evaporation and the rainfall on the lake surface balancing. I have not gone into that, so I am not prepared to state—

Q. I am not speaking of local supply.

A. The local supply is involved in the evaporation and in the rainfall on the lake surface itself, as well as the run-off. I do not wish to make any assumptions involving the evaporation on the lake surface. I think it is a thing that we have not determinate information about.

Q. You stated a little while ago you thought the local supply from Lake Erie was approximately 7,000 feet?

A. I stated that as the run-off given by Mr. Williams, without raising any question as to the validity and correctness of rainfall observations or evaporation used by Mr. Stearns, I use that value for the run-off and Mr. Stearns value for the evaporation or rainfall, and it places this whole chain of lakes in consonance, that is the discharge of the various rivers.

Q. I am asking you what your opinion is as to that percentage due to the local supply?

A. Not knowing the evaporation, in other words the water that flies off or flows away through the air from the lake surface, I am unable to give you a statement of that.

Q. Then you don't know?

A. I don't know.

Q. You never made any independent investigation?

A. No.

Q. Of your own?

A. No.

Q. You don't know from any of the investigations that have been made in this case?

A. I have Mr. Stearns' figures as to the evaporation.

Q. But you say all those are in accord, these conclusions, Mr. Williams' conclusions are in accord with the general physical conditions, your various increments and so on; and yet you do not want to give an opinion as to what the local supply is. Is that true?

A. Well, I should say it was very close to the amount indicated in my analysis.

Q. What percentage of the discharge of Lake Erie is the local supply?

A. Perhaps three or four per cent. Now I am speaking of the months June to November, inclusive.

Q. We are talking about the whole thing?

A. I do not know.

Q. You do not know about the whole thing?

A. I have not made any analysis which involves the whole thing. I do not know whether Mr. Williams' figures, I have no means of knowing whether Mr. Williams' figures for the whole year are correct or not. That includes the winter season when the flow of the streams would be somewhat in doubt and the precipitation of snow, water in the form of snow, being somewhat in doubt. I do not know.

Q. By what per cent. does this local supply vary from year to year?

A. I have made no investigation of that.

Q. You do not know anything about it. What proportion of the discharge, according to your best judgment, is the evaporation from Lake Erie on the average?

A. I do not know.

Q. You do not know that. By what per cent. does the evaporation vary from year to year?

A. I do not know.

Q. Do you consider the evaporation to vary in a greater or less proportion than the rainfall, from year to year?

A. I would not wish to make any statement on that.

Q. Does it vary less?

A. It would depend on the other elements, the temperature and distribution of the rainfall, general humidity; and I could not reach any conclusion concerning it.

Q. What is the variation of rainfall from year to year on the drainage of Lake Erie?

A. That is indicated in tables printed by Mr. Wheeler in his 1903 report; tables I believe given in Mr. Williams' Exhibit 34, which will indicate that. I could refer to those tables.

Q. Well, to refresh your recollection, the mean rainfall as given by Mr. Wheeler was 34.08 inches, wasn't it?

A. I had it in mind as 34 inches as an average rainfall.

Q. And the range was 40.23 inches in 1890, to 28.41 inches in 1895, wasn't it? That is 24 per cent. to minus 25 per cent.?

A. In Mr. Wheeler's table on page 2879 of the report of the Chief of Engineers for 1903, the annual rainfall is not summed up by Mr. Wheeler, but I see pencil figures placed here, which I may assume to be correct. These were made by Mr. Gardner S. Williams. The average appears to be

34.14; the maximum is 40.23, and the minimum is 28.41. That is the year 1895, when the lakes were so low.

Q. That would be 24 per cent. to minus 25 per cent. variation, wouldn't it, or 25 per cent. in both directions?

A. A little less than that. That is taking 34.14 as the base, 40.23 is 6.09 greater; divided by 34.14, that would be about 17.8 per cent.

Q. That is the variation?

A. That is the variation for the maximum from the mean.

Q. It is practically the same for the variation from the minimum?

A. Yes, very close to the same for the minimum.

Q. Assuming that there was an excess of 8,000 cubic feet per second more water delivered to Erie in the period from 1860 to 1882, than in the period from 1890 to 1901, as shown by the computation of Mr. Haskell, on page 2259—105 of the typewritten record (printed record page 2734), and assuming that it was disposed of by evaporation from the surface of Lake Erie, how much evaporation would this represent on Lake Erie measured in inches, if distributed through the Open Season?

A. During the six months, June to November, it would represent about five inches; that is the 8,000 would correspond to five inches.

Q. Wouldn't it be seven inches?

A. No.

Q. Then you disagree with Mr. Haskell's answer to this question?

A. I do not remember Mr. Haskell's answer to this question.

Q. Wherein he said it was three inches, which he finally corrected to four inches, as appears on page 2259-108 (printed record page 2736).

A. I am simply figuring it this way: Having 8,000 cubic second feet of water to dispose of in 183 days or six months, June to November, inclusive, the lake would be lowered five inches in disposing of that water, below five inches.

Q. Did you not at the time Mr. Haskell gave his answer check his computation and agree with it? You were present were you not?

A. Yes, I was present. I am not certain.

Q. You do not remember that. In your direct examination you stated that in deriving the Niagara increment, the witnesses for the defendant in this case started at the St. Lawrence with an inflated increment, did you not?

A. Yes.

Q. How was that inflated?

A. By Mr. Williams' chronological method of grouping the observations.

Q. How much was it inflated?

A. From 28,900 roundly to 30,300. I am not quite certain of the last figure.

Q. What per cent.?

A. That is not quite an accurate statement that I gave there of 28,870. That should be the figure I got out yesterday, 24,000.

Q. Wasn't the 28,870, the increment that was given by the Government witnesses in this case for the St. Lawrence River?

A. That was for the St. Lawrence River at Ogdensburg, ant that should be corrected by two per cent. The 30,300, was for Oswego for Lake Ontario.

Q. You said it should be corrected for Oswego, Mr. Shenehon. Didn't you say in your testimony early in this case that that increment which was given was substantially correct for Oswego?

A. I think the U. S. Exhibit Number 2 covers that.

Q. I am asking about your testimony?

A. I have no recollection of making any such statement. It is within two per cent. of correct, so if you wish to call that substantially correct, that would be 7.1 per cent., as I make it, of inflation. I reduce that to Oswego, which gives an increment for Oswego of 28,300. That is correcting by two per cent.

Q. You say that is seven per cent.?

A. A little over seven per cent. I make it 7.1.

Q. You change the increment then, you reduce it two per cent. for Oswego, do you?

A. Yes.

Q. But you stated in your direct examination, didn't you that that increment was substantially correct for Oswego?

A. I am not aware of that fact. I think I stated the increment as indicated on U. S. Exhibit Number 2, where it appears for Oswego you must reduce the increment two per cent.

Q. Well now you stated in your examination, re-direct examination, that this increment for the St. Lawrence River might be ten per cent. in error, didn't you?

A. Yes.

Q. You are also aware that Mr. Williams in arriving at

the increment which he used for the St. Lawrence River made certain calculations, aren't you?

A. Yes, which I regarded as erroneous, and in the absence of knowledge as to the lag or time interval in the river, he set his gage elevations ahead, as you recollect.

Q. But the seven per cent. which he used for the increment, which he used, was within the ten per cent.?

A. Yes, that is true.

Q. Which you described as being in error, didn't you?

A. Yes, that is true. Of course my present opinion is that the error was on the other side. It was greater than the ten per cent. indicated.

Q. That the increment was greater. Did you indicate that in your direct examination?

A. No, that was not stated.

Q. And it was not your opinion at that time, was it?

A. I think I had not made any further investigation by the method of relative fluctuations to—

Q. Yet you say that Mr. Williams' determination there from those discharge observations which was within the ten per cent. as you stated that the increment might be in error, was still an erroneous conclusion?

A. His method of treating the observations, to my mind could reach no other—did reach no other conclusion than an erroneous result; that the method was vitally and fundamentally wrong.

Q. And not based upon any logical reasoning at all, as an engineer?

A. Based on an ignoring of the facts.

Q. And as a foolish and unnecessary calculation, is that correct?

A. I do not like to characterize Mr. Williams' work.

Q. I am asking you with reference to Mr. Williams' computations as an engineer there?

A. The investigation and the method used by Mr. Williams, in my judgment, are not those that would be used by an investigator with full knowledge of the facts.

Q. And still his determination is within the ten per cent. which you stated?

A. Yes, within seven per cent., roundly.

Recess to 2:00 P. M.

After Recess 2:00 P. M.

FRANCIS C. SHENEHON resumed the stand and testified on cross-examination further as follows:

Mr. Adcock: Q. Now, Mr. Shenehon, I asked you a question, which I think was the first question beginning with the cross-examination yesterday, and you stated that you would not like to answer that question until you had an opportunity to plot up the observation shown upon Haskell's Exhibit A, of February 25, 1914. I understand that those observations have been plotted, and I will now ask you if you will answer the question first put to you?

A. I have before me a plot of the observations which were presented to me, and this plot is in three parts corresponding to the three series indicated by the tabulation forming part of the question.

Q. You understand that that plotting was made by Mr. Murray Blanchard, don't you?

A. This plot was made by Mr. Murray Blanchard, an engineer in the Sanitary District Engineer's Office, and I am assuming it is correctly plotted.

I find that the observations in columns 1 and 2, when plotted, show that the discrepancies indicate no very clear cut law of relationship.

I find that the observations in groups 3 and 4, columns 3 and 4, in which there are 27 individual observations, are in fair alignment, but not in alignment with the observations of groups 1 and 2. And I find the observations of groups 5 and 6, align themselves fairly well along a line, and that line is not in accord with the line indicated for columns 1 and 2. The choice, under these conditions, I think would rest with groups 3 and 4, on account of the greater number of observations and somewhat greater range in the fall. The choice, however, is not a very clear cut one. I am not sure that the question itself is entirely comprehensible, after plotting these observations.

We have three groups of observations, and neither one of the groups appears to be in accord with the other group. I hardly see how a clear cut determination may be made as to which of the two groups may be chosen to get the condition represented here, unless I state neither.

Q. Your choice lies between 3 and 4?

A. I cannot see that there is any very close relationship

between the observations in 1 and 2, with those of 3 and 4, or 5 and 6.

Q. You think that neither one of those groups is applicable to the assumed conditions of columns 1 and 2?

A. The assumed conditions of columns 1 and 2 are somewhat remarkable. We have, for instance, from a mean line which I have drawn, which is of course only approximate, I did not take out centers of gravity,—I have stretched a line and the observations are such that the bearing of the line cannot be very accurate, the observations themselves are so discrepant; I speak of observations in columns 1 and 2 now. For instance, we have a residual in groups 1 and 2 of approximately a foot and a half from the mean line; and if we take the residual in the other direction, it is about .7 of a foot. We have other residuals approaching that in size.

Q. You think it would be improper Mr. Shenehon, I understand it is your opinion, to derive a discharge curve from either set of observations, to be applied to the conditions of columns 1 and 2?

A. The question itself is really incomprehensible to me. I confess my inability to get a clear comprehension of the thing. We have three sets of observations shown and columns 1 and 2, represent real conditions, actual conditions, as I understand. Just what these observations are, I don't understand where they come from, if they are not real conditions.

Q. They are real conditions also. Mr. Haskell seemed to be more alert than you?

A. Mr. Haskell is a very alert man.

Q. He considered it was possible to form an opinion with reference to the very identical question I asked you.

A. Mr. Haskell, I believe, did not see the observations plotted.

Q. But from the records shown on the Exhibits there, he was able to form an opinion, wasn't he?

A. I think the testimony indicates that. I don't remember what his conclusion of the matter was.

Q. And you have no choice then as to which column—

A. I say the thing is incomprehensible to me.

Mr. Hopkins: Are those figures in evidence?

Mr. Adcock: Yes.

Q. Now, do you wish to devote any further study to that question, Mr. Shenehon?

A. I might take it under advisement, see if I can really comprehend the thing.

Q. Mr. Haskell answered the question very quickly, readily. He grasped the words, the expressions—

Mr. Hopkins: Objected to. We cannot know what another man grasped or understood.

Mr. Adcock: Q. Now, can you make any choice as between columns 3 and 4 and columns 5 and 6, as to which one is more applicable to the conditions indicated in columns 1 and 2?

A. I have stated that columns 3 and 4, have a greater number of observations. That is an advantage, and there appears to be a greater range in the difference in elevation, or difference in fall. So as far as those elements are concerned they appear to favor 3 and 4; the observations appear to be a little more accordant in 5 and 6. Viewing them that way, that appears to be a group of observations that align themselves well with a little less length in the fall, or height in the fall. The trend of the line for the 5th and 6th, is nearer parallel to the trend of the line for the group 1 and 2.

Q. Which do you choose, then?

A. I do not make any choice. I give you the elements in each, the advantages in number in one case, a little better in accord than the other, a little better accord with the line.

Q. Mr. Shenehon, the court will not know anything about these reasons you give. You are an expert witness and we are asking for a conclusion, and I am asking you to give me your choice between columns 3 and 4 and 5 and 6.

Mr. Hopkins: Objected to as already answered. He has no choice.

The Witness: I have given my answer that the question is an incomprehensible one to me; and I have pointed out that we have groups of observations here with certain peculiarities. I do not wish to make any choice.

Mr. Adcock: Q. I know, but you have mentioned certain things which might lead you to make a choice.

A. Yes; they are not sufficient to permit me to make a choice.

Q. Then you haven't any opinion as to which one?

A. I should prefer to make no choice.

Q. Would you as an engineer, use one group as readily as another?

A. For what purpose? I cannot see the relation of groups 1 and 2 to the other two.

Q. For the purpose of making a choice?

A. I cannot see any relation. I can't see the rationale of what we are attempting to get at.

Q. I am asking you to suppose that you desired to obtain

a discharge curve for this section at which the observations in columns 3 and 4 and 5 and 6, were made, that would represent the discharge of the period referred to the head at the up-stream end?

A. What is the relation of groups 1 and 2? That is what I can't make out.

Q. (Continuing.) Assume it is made at the same section, same river. You have three groups, in the same section and the same river. If you will read the question, you will find that the conditions are all assumed there.

A. You mean I am to choose between the three groups?

Q. No, between the two?

A. I can't see the relation between groups 1 and 2.

Q. Between columns 5 and 6, and columns 3 and 4?

A. Well, I repeat that I do not comprehend the question.

Q. In other words you want us to state to you what the next question will be. Is that right?

A. I want you to make the thing comprehensible to me.

Q. I am asking you to answer the question as it has been put to you, to give your opinion as to the choice that you would make between the groups of observations there as applicable to the conditions assumed in columns 1 and 2?

A. You mean assuming three groups of observations, I am to say which group I regard as the best?

Q. No, just read the question? (Question read as follows:) "I am asking you to assume that suppose for a certain channel similar in magnitude to those connecting the Great Lakes, but without such rapids or falls as occur at the Soo, and Niagara, for a period of years the elevation of the water at the up-stream end had been as shown in the first column, and the fall through the channel had been as shown in the second column," do you understand what that first and second column represents?

A. Yes.

Q. (Continuing.) "Suppose it were desired to obtain a discharge curve for this section that would represent the discharge for the period referred to the head at the up-stream end, and suppose that there had been made a series of 27 observations under the conditions of columns 3 and 4; and that there was also available a series of 23 observations made with equal care, under the conditions shown in columns 5 and 6. Which in your judgment would give a discharge curve the more closely applicable to the assumed conditions of columns 1 and 2?

A. I believe I can't answer that question.

Q. On what ground?

A. I have already stated that each of these lines has some elements that appear to be superior to the other. The upper one, which is 5 and 6, the trend of the line appears to be a little nearer in accordance with the trend of the line in 1 and 2, but the observations in 1 and 2, are so discrepant that they cannot have any great value.

The range in 3 and 4 in the backwater effect or the fall there is greater than in 3 and 4; and more nearly in accord with the line in 1 and 2. The range in each, I believe, is pretty nearly the same, that is for the elevation, so there is not any great choice there. In 3 and 4, we have the more observations. In 5 and 6 we have a little better accord. I would have great difficulty in choosing between those.

Q. Now Mr. Shenehon, you have stated various facts concerning the different groups there?

A. Yes.

Q. I am asking you to weigh those considerations which you have mentioned and give me a conclusion as to which group, columns 3 and 4, and 5 and 6, are most applicable to the condition assumed in columns 1 and 2?

A. I think I have given you the best answer I can, Mr. Adcock.

Q. If you had to use one or the other to obtain a discharge curve, which one would you use?

Mr. Hopkins: Objected to as already answered; that he has no opinion.

A. What I can't comprehend is what 1 and 2 represent.

Q. That is not the question, as to what you comprehend about that.

A. Then I can't answer the question, can I?

Q. If you were going to obtain a discharge curve for that section of that river, which would you use, the group in columns 4 and 5 or columns 5 and 6?

A. You have attached to your question certain assumptions in columns 1 and 2. I do not comprehend that.

Q. I am asking you to assume: Suppose for a certain channel similar in magnitude to those connecting the Great Lakes, but without such rapids or falls as occur at the Soo and Niagara, for a period of years the elevation of the water at the up-stream end had been as shown in the first column, and the fall through the channel had been as shown in the second column. Those are certain assumptions to make, with reference to columns 1 and 2.

Mr. Hopkins: Same objection. The witness says he has no opinion.

Q. And I am asking you to suppose that you desire, as a hydraulic engineer, to obtain a discharge curve for this section that would represent the discharge of the period referred to the head at the up-stream end, and suppose that there had been made a series of 27 observations under the conditions of columns 3 and 4, and that there was also available a series of 23 observations made with equal care under the conditions shown in columns 5 and 6. Now, which in your judgment, would give a discharge curve the more applicable, more closely applicable to the assumed conditions of columns 1 and 2. I want you to make a choice. You have stated various reasons that might enter into making such a choice. If you were going to obtain a discharge curve as indicated in the question, would you use either one of them?

Mr. Hopkins: Same objection. He says he would not.

Mr. Adcock: Q. You may use one or the other, is that the point?

A. I am not sure I would wish to use either of them.

Q. If those were the only observations you had and it was necessary to obtain a discharge curve, which one would you use as between columns 3 and 4 and columns 5 and 6?

A. I have stated that the thing is rather incomprehensible to me, and I have not any very clear cut choice. The greater number of observations there appeals to me, with the greater range, and if you wish a mild choice, I might say 3 and 4 is preferable.

Q. Do you consider the observations shown in 3 and 4, equally applicable, at least as applicable as those shown in columns 5 and 6?

A. Yes, or a little more so on account of the greater number under greater range.

Q. And you make your choice as between the two, columns 3 and 4?

A. Yes. You understand this is not a very clear cut choice, and I am not sure in the end that either of those is entirely applicable to the conditions shown in 1 and 2. The thing is rather obscure, you understand, in my mind.

Q. Do you wish to make the statement that neither one is applicable to the conditions assumed in columns 1 and 2?

A. In columns 1 and 2, as I stated before, the discrepancy of certain observations from any line, the scattering of them is so wide, that it is rather difficult to make a statement along this line.

Q. I am asking you for your opinion. I know it is difficult. There are lots of difficult questions about this case, and I appreciate also, Mr. Shenehon, that you want to be very careful about your answers.

A. Yes.

Q. And that you are cautious and everything like that, but we would like to have you answer the question as to your choice.

Mr. Hopkins: Objected to. The witness has already answered.

Mr. Adcock: Q. I mean as to whether either one of them is applicable to the conditions assumed in columns 1 and 2?

A. I should wish to make further computations to see whether or not a line derived from groups 1 and 2, would coincide very closely with lines 3 and 4. They do not appear to in the lines that I have drawn, by stretching a thread, or a string, to speak more accurately. They do not appear to coincide. They appear to be of fairly wide divergence. The law of relationship is not the same for 1 and 2, as it appears, as that in 3 and 4.

Q. Do you think you could obtain more accurate results if you used a thread than the string that you did use in this case?

A. I do not think that would change the thing very much, but it would be well to take out the center of gravity and put the thread through that at least. But where you have discrepant observations, as you have in columns 1 and 2 here, a thread has its difficulties as well as the Three Point Method, and even the method of Least Squares.

Q. You now wish, Mr. Shenehon, to obtain the center of gravity and show that center of gravity, before you attempt to use it?

A. That center of gravity, in the Three Point Method and Least Square Method, they both pass through that point, on the assumption it is a straight line.

Q. In the latter exhibits which the Government has presented in this case since Mr. Williams has testified, you have shown the center of gravity on the exhibits, haven't you?

A. Yes.

Q. That was not shown on the previous exhibits?

A. I think Mr. Williams has contributed the center of gravity to be set as a central pivotal point where we have a straight line relationship. It confirms the stretching of a

thread with a little higher precision and it is, as I say, a point on the Least Squares derivation.

Q. Notwithstanding your opinion of some of Mr. Williams' methods in analyzing the observations that have been presented in this case, you think he has made some contribution to the Lake Survey in their work in determining the discharge curve?

A. I am very glad indeed to acknowledge whatever Mr. Williams has contributed. I am delighted always to have a chance to acknowledge anything of that kind.

Q. He might be a valuable adjunct to the Lake Survey, might he not?

A. (No response.)

Mr. Hopkins: Objected to.

Q. If the elevations in columns 1, 3 and 5, should have been 200, 300, or 400 feet, or any number of feet higher in every case, would your answer be the same?

A. Yes.

Q. That is axiomatic, is that right, Mr. Shenehon?

A. Yes.

Q. You are willing to make answers with reference to any question which involves an axiom in the engineering profession?

A. In so an intelligent a court as this, axiomatic conclusions need not be set down.

Q. 8,000 cubic feet per second equals how many feet in one year?

A. That would be 252,288,000,000.

Q. What is the area of Lake Erie in Square feet?

A. Including Lake St. Clair?

Q. No, Lake Erie?

A. In computations concerning this, we generally include the two.

Q. Include it if you wish?

A. That would be, Lake St. Clair included, 292,964,000,000 square feet; with 1 foot depth, would be cubic feet.

Q. What depth of water in inches would have to be evaporated during the year to dispose of an inflow of 8,000 cubic feet per second?

A. That has been already given as a little over five inches.

Q. No, I am asking you to figure that from what you have learned?

A. The statement of five inches included six months.

Q. How much would have to be evaporated to do it in six

months, to take care of 8,000 cubic feet per second inflow in six months?

A. Well, a continuous flow?

Q. If 8,000 cubic feet of water per second annually came into that lake, that had to be gotten out by evaporation, and you were going to evaporate it in six months—

A. My answer to the question where I stated five inches in depth on the surface of Lake Erie and Lake St. Clair, if it was disposed of in six months, would be equivalent to a flow of approximately 8,000 cubic second feet.

Q. Now, I have asked you to figure what 8,000 cubic feet per second would represent in cubic feet in one year. I asked you to take the area of Lake Erie including that of Lake St. Clair. Now, I ask you to state what depth of water in inches would have to be evaporated during the year to dispose of an inflow of 8,000 cubic feet per second annually. You have the cubic feet of water and the area of the lake surface, St. Clair and Erie. Now, isn't it a simple proposition that you would divide 252,288,000,000 by 292,964,982,600 and that you would get as a result about .75 of a foot?

A. It would be about .86 of a foot, a little over 10 inches. It would be just twice the amount that I stated before. I said a little over five inches; this would be a little over ten inches.

Q. Then do you wish to correct your statement?

A. My answer before was based on the flow at the rate of 8,000 cubic second feet over a period of six months, equivalent to a depth of five inches. That same amount flowing for a year, of course, would be twice as great; ten inches.

Q. If you had to dispose of this amount of flow in six months, would the evaporation be any less?

A. Well, are you assuming now that you have fixed conditions at the outflow, or if we have a higher elevation of the lake we have a higher outflow.

Q. Assuming the conditions as they existed, that there was 8,000 cubic second feet of water throughout the whole year to be disposed of by evaporation from Lake Erie, we ask what depth it would be. Mr. Haskell answered three inches. We called your attention to his figure and you checked it?

A. The ten inches appears to be correct. If however, you assume an 8,000 cubic second feet inflow and take into account the higher elevation and therefore the difference in condition at the outflow, you might reach a different conclu-

sion if it was an element in the question, which I understand it is not.

Q. Not an element?

A. Simply getting the relation between depth on the lake surface and the cubic feet per second over a certain length of time.

Q. Assuming as you testified this morning that the average depth of the Niagara River from the Buffalo gage to Chippewa was 16 feet—

A. That is an approximation gotten by glancing at the map.

Q. If you want to glance again and change the figure, all right. Do you wish to change your statement made this morning?

A. If any material change were made, I would wish to spend two or three hours in making a more elaborate computation. This for approximate purposes may be sufficient.

Q. Continuing the question: And from the Buffalo gage to the bridge, it was 20 feet?

A. Yes.

Q. And that the rapidity of translation of a change at Buffalo would vary as the square root of the depth, as you also testified today and yesterday, what percentage of the time of transmission to Chippewa would be represented by the time of travel to the bridge?

A. I would have to scale off the distances accurately, in order to reach a conclusion.

Q. You stated I believe, in answer to a question, that the distance from the Buffalo gage to the International Bridge was 3 miles?

A. Those are round numbers. I will endeavor to get that a little more accurately. (Examining chart.) 3 4/5ths miles.

Q. 3 4/5ths miles from the Buffalo gage to the Bridge, is that correct?

A. That is correct.

Q. The distance as you have scaled it from the Buffalo gage to Chippewa is what?

A. An average of 16 miles—not from Buffalo gage, from the Bridge to Chippewa is 16 miles, and 3 4/5ths, 3.8.

Q. That would be how many miles from Buffalo to Chippewa?

A. That is an average of 19.8 from Buffalo gage to Chippewa. We have spoken of it roundly as 20 miles. It is a little

more by the American channel, and a little less by the Canadian channel.

Q. Now, having done the scaling which you said was necessary in order to answer the question, will you answer the question which I answered you?

A. Will you read the question?

Q. (Question read as follows: "Assuming, as you testified this morning, that the average depth of the Niagara River, from the Buffalo gage to Chippewa was 16 feet, and from the Buffalo gage to the Bridge it was 20 feet; and that the rapidity of translation of a change at Buffalo would vary as the square root of the depths, as you also testified today and yesterday, what percentage of the time of translation to Chippewa would be represented by the time of travel to the Bridge"?)

A. I make the time of translation from the Buffalo gage to the Bridge 14 minutes and from the Bridge to Chippewa—

Q. No, the percentage?

A. I will give you the percentage after stating the quantities.—62 minutes. The aggregate time is 76 minutes.

Q. Wait a minute: I am asking you as to the percentage?

A. I am about to figure that now, after having expressed the factors entering into the determination. 18 per cent. and 82 per cent. are the two percentages.

Mr. Hopkins: The time to the bridge is 18 per cent. of the time to Chippewa?

A. Yes. Of the whole time between the Buffalo gage and Chippewa; 18 per cent. is consumed in travel to the Bridge, and 82 from the Bridge to Chippewa.

Mr. Adcock: Q. Now assume that the time required for a change to travel to Chippewa is two hours, how long will it take this change to reach the Bridge?

Mr. Hopkins: You mean upon the same assumption?

Mr. Adcock: Yes, based upon his answer.

Mr. Hopkins: Based upon his answer to the former question?

A. About 21 minutes, based upon that percentage relationship.

Mr. Adcock: Well, assuming it is 2 hours and 15 minutes, which is the minimum you stated this morning, how long would it take the change to travel?

A. About two minutes and a half longer; it would take about 24 minutes.

Q. And if it were 2 hours and 40 minutes?

A. About 29 minutes.
Q. If it were 3 hours?
A. About 32½ minutes.
Q. Four hours?
A. That would be about 43 minutes.
Q. And 5 hours?
A. Let us see where we are on this: That is from the Buffalo gage down to the Bridge, on the assumption that it took—
Q. On the assumptions of your answer to the previous question?
A. I would like to recast those answers. Give me your various times, first, 2 hours?
Q. 2 hours and 15 minutes, 2 hours and 40 minutes, 3, 4, 5 and 6 hours?
A. Now let me answer these consecutively.
Q. Use any order you choose.
A. Proportionally, or the proportion of time from the Buffalo gage to the Bridge under the assumptions made, if the total time between the Buffalo gage and Chippewa were two hours, it would be 21 minutes to the International Bridge; if 2 hours and 15 minutes, 24 minutes; if 2 hours and 40 minutes, 29 minutes; if 3 hours, 32 minutes; if 4 hours, 43 minutes; if 5 hours, 53 minutes; if 6 hours, 61 minutes.
Q. Now Mr. Shenehon, how about that eight minute interval that you used,—which you did not use and Mr. Moore used in connection with your measurements, what value was that?
A. I believe it is a sufficient value for getting at the volume of flow with no error chargeable on this account, if this would appear in the end to be the correct interval instead of the eight minutes or ten minutes used, and so far as the increment is concerned, a similar statement follows?
Q. You might just as well say 2, 3 or 4 minutes, any number of minutes, make a guess at it, mightn't you?
A. I have already made a statement, whether the ten minutes was used or was not used, in my judgment, has no bearing on the conclusion as to increment and volume of flow of a group of observations. A single observation would probably be a little closer if you observed the time interval.
Q. But the value that you used there for the travel was 300 per cent. wrong almost, wasn't it?
A. No, I do not regard this as conclusive. We have as-

sumed roughly the depths. We have assumed a formula that is a theoretical one.

Q. That is based on the two hours, isn't it?

A. No,—

Q. If the calculations are correct, the facts which you have stated in your testimony, and from which you have drawn these conclusions here, and you assumed at the time of travel between Buffalo and Chippewa is two hours, which you stated, you are almost 300 per cent. wrong on the time of travel?

A. Assuming these figures we have just made to be absolutely correct.

Q. How much do you think they are off?

A. Well, I would expect to make a rough statement of the depth in the two cases, take a mean length of channel as we have done on the both sides of Grand Island, I should expect to have some variation if this were done more carefully. In the end, I would not expect the text book equation to be entirely applicable.

Q. What better methods have you used to determine the eight minute travel?

A. Observations.

Q. On what?

A. At the International Bridge made with the—

Q. For how long a time?

A. I think I stated half a day, and yet I am rather hazy whether it might have been a day or half a day.

Q. What do you consider it would be by taking a week at Chippewa?

A. Well, I consider that the cases are very different. The changes between the Buffalo gage and the International Bridge are exceedingly intimate. They are close together, fairly deep water between.

Q. You think a half a day would be sufficient to determine that?

A. Yes, for the substantial accuracy that is required in the lag. In fact I stated if we did not observe the lag at all, as Mr. Sabin did not in the St. Clair River, I think we would not get any error.

Q. If you were three or four hundred per cent. wrong, or five hundred or six hundred per cent. wrong on your calculations as to the travel, it would not make any difference?

A. When you get into these small quantities and talk about big percentages, you are rather distorting the thing.

Q. If the real time of travel between Buffalo and Chippewa were five hours as the figures this morning indicated, going over the gage records from November 1st to November 6, 1906, covering a week, then you were 500 per cent. wrong, weren't you?

A. You do not understand that I accept the conclusion drawn from your figures given this morning? I have put into the record the lag at Suspension Bridge and the Whirlpool which are well below Chippewa in the river, where we get this out with excellent determination, and the maximum lag at Chippewa, in my judgment, does not exceed two hours and 40 minutes.

Q. Does not exceed that?

A. No.

Q. You think you could determine that lag between the Buffalo gage and the International Bridge in half a day, but you could not determine it in taking the observations running over a week as to Buffalo and Chippewa, is that right, determine the lag at Buffalo and Chippewa?

A. Our examination indicated that Chippewa was not a favorable place to determine the lag. It is hard for me to conceive as a physical fact that the lag is greater between Chippewa and Buffalo than between the Gorge and the Whirlpool, which are down the river three or four miles further.

Q. We will go on a little bit further. Maybe we can contribute something more to the Lake Survey. In how many instances was the observed lag to the Suspension Bridge as shown on sheets which you presented this morning, numbered 1, 2, 3, 4 and 5, and entitled "United States v. Sanitary District of Chicago, determination of lag between Buffalo and Suspension Bridge gage, time required for change in Lake Erie to reach Suspension Bridge; only days of well marked changes used in determination," in how many instances was that equal to six hours?

A. You are asking now with respect to the Suspension Bridge gage?

Q. Yes. That is the nearer gage, isn't it?

A. Yes, that is the one—

Q. It is immediately below Chippewa?

A. Three or four miles below Chippewa. I find in the month of October, 1907, out of 23 determinations on high water and 22 on low,—I do not find any lags in excess of 5.5.

Q. Will you answer my question: I am asking you with reference to six hours. How many were six hours?

A. On the sheet marked November, 1907, in which 23 determination of marked high water are shown and 21 of marked low water, I find—

Q. Do you find one, just calling your attention to sheet number 1, under date of the 12th of October, 1907?

A. The answer should be, 1 on the first sheet; on the second sheet I find 2. On the third sheet, I find 2; on the fourth sheet I find 1. On the fifth sheet, I find 4, one of these being seven hours. I understood your question to be six hours or in excess of six hours?

Q. Yes? How many five hours to 5½ hours?

A. Would you prefer to have me count these up and simply give the results?

Q. Yes?

A. How many did you make for six hours?

Q. 10.

A. I find 2.

Q. Between five hours and five and a half hours?

A. I misunderstood the question. I will recount that: 21.

Q. How many were there four to four and a half hours?

A. I get 55.

Q. How many altogether, Mr. Shenehon, that were four hours or more?

A. 86 is my count.

Q. You had, I believe, 111 observations, didn't you?

A. Twice that many, roundly.

Q. What?

A. Twice that many; 111 on the high water and approximately the same on the low water. I counted both the well marked high water and the well marked low water.

Q. Now, at the Suspension Bridge and the Whirlpool, there are recording gages, aren't there?

A. Yes, those were self-recording.

Q. There was one at 7 hours, I believe, was there not Mr. Shenehon?

A. Yes, one at 7 hours.

Q. They are all automatic, self-recording gages?

A. Yes.

Q. How many zeroes do you find?

A. I don't find any.

Q. How about the sheet number 1; observation on the 11th for falling water?

A. Yes, there is one on the 11th, that is right.

Q. How many where there is one hour given as the lag?

Mr. Hopkins: You mean less than one?
Mr. Adcock: One or less.
A. You want me to count the zeroes in that?
Q. No, between zero and 1, ignoring zero?
A. I find seven of 1 hour.
Q. Seven of 1 hour?
A. Yes.
Q. How many between 1 and 2 hours?
A. I find 58 between 1 and 2.
Q. How many between 2 hours and 2.5 hours, or including 2.5 hours?
A. You mean including the 2 also?
Q. Yes, better include the 2.
A. That has already been included.
Q. Did you include the 2?
A. I included 2 and 2½.
Q. What?
A. It included 1½ and 2.
Q. Did it include anything between 1—?
A. No, did not include 1; 1½ and 2.
Q. How many have you got at 2 hours and a half?
A. Fourteen.
Q. That makes altogether how many 2½ or less than 2½?
A. That makes 80.
Q. Eighty?
A. Yes.
Q. Do you think it would be physically possible for a change at Buffalo to appear at Chippewa before the Buffalo change took place?
A. Not as a matter of causation, no.
Q. Do you think it would be physically possible for the same thing to take place at the Suspension Bridge?
A. In advance of the cause?
Q. Yes?
A. In the outflow of Lake Erie?
Q. Yes?
A. No.
Q. Do you think it physically possible for a change to take place at the Suspension Bridge at the same time that a change took place at Buffalo?
A. No.
Q. Do you think it physically possible for a change at the Suspension Bridge to take place within 1 hour after a change at Buffalo?

A. I think we are now getting into the region of possibilities.

Q. You think it could be physically possible?

A. Yes, I could understand the condition, I think, where it might happen that way.

Q. What would accelerate the travel so that it could possibly travel from Buffalo to the Suspension Bridge in one hour?

A. An exceedingly sharp rise might have the effect of sending the stream in a virtual bore down the river more rapidly than ordinarily.

Q. That is if the rise is very sudden, you consider that the travel of the crest is faster, do you?

A. I don't wish to—

Q. You base your answer upon that?

A. I could give an illustration: We had the breaking of the Johnstown Dam, at one time, in which a wall of water traveled down through the valley at an exceedingly rapid rate. Let us duplicate that situation at the head of the Niagara River. You have an exceedingly rapid rate; I would not be willing to state the lower limits of the time that might be taken.

Q. Do you think it would be more rapid than under ordinary circumstances?

A. Yes, I should think so.

Q. You feel very sure of that?

A. Yes, I think the rate of travel of a bore of that kind might be more rapid than the ordinary slower rise of the water.

Q. Have you got any observations?

A. No, I haven't anything to support that.

Q. Just an opinion?

A. Yes.

Q. You think it would be fairly possible for a change to take place at Suspension Bridge within an hour and a half after the change at Buffalo, do you?

A. Yes.

Q. And within two hours?

A. Yes.

Q. And within two hours and a half?

A. Yes.

Q. And that there might be conditions which would so accelerate the travel, so that the crest could travel from Buffalo to the Suspension Bridge in two hours and a half?

A. Yes, I could imagine extraordinary conditions.

Q. Then you think it would be fair, as an engineer, to include these 80 observations, do you, where the travel was less than two hours and a half?

A. Yes, I would include the one, and have included also the one in which the travel is indicated as zero, for the reason given this morning, that is an individual observation subject to the error of observation; and it would be ridiculous to reject your observations because they happen to be on the small side, and retain the observations that happen to be on the large side, because you have got to have the small ones in order to balance out the effect of these that are unusually large, and so we have the error of observations coming in.

Q. You selected what you call marked changes, didn't you?

A. Yes.

Q. "Well marked" you call it?

A. Yes.

Q. And in selecting those, you plot them, don't you so as to show a line?

A. No.

Q. Or you compare the elevation?

A. They were selected directly from the gage sheets.

Q. You did not use the care with reference to that, then, that you did this morning with reference to plotting the observations shown on Haskell's Exhibit A. You wish to have these plotted before you give any opinion?

A. That is a matter of the variation of a line showing a relation. It is quite a different affair.

Q. But when you found a crest at Buffalo, which you say indicates a well-marked change—

A. Yes.

Q. —it is your desire then to find something at the Suspension Bridge that will correspond with that in some way, isn't it?

A. The procedure is to follow down picking out the hours. You understand I did not do this myself.

Q. Did you leave that to Mr. Souther?

A. That was done by Mr. Souther, my assistant.

Q. He is the same gentleman who prepared the other two papers entitled somewhat the same way, with reference to Chippewa?

A. Yes, I may say—

Q. Did he prepare any other papers used in this case?

A. Yes.

Q. What?

A. He was my assistant in the preparation of a great many of these papers.

Q. Did you check over his figures?

A. Yes, usually.

Q. Did you check these?

A. No, these particular figures have never been checked by me.

Q. Now, the procedure is to pick out well marked changes during the day, at say, for instance you have here October 1st, 1907, you would pick out the change at the Buffalo gage which is well marked during that day, would you, or would he?

A. That I believe was the procedure, follow down pick out the—

Q. What hour—

A. Let me state my recollection of how this was done. I think he picked out for each day the low point and the high point.

Q. That is at Buffalo?

A. Where there was a wavering in the line, so that that was not well marked, that day was not included. You will notice in these tabulations that there are perhaps 23 out of 31 days utilized, and pursuing a similar procedure in regard to the Suspension Bridge gage, and setting down the times, you have the relationship.

Q. And then if a crest—

A. Answering the question you propounded a short time before: These all have been plotted and are shown in what has been mentioned as the Three Curve Series, so these tabulations are subject to corroboration by reference to the Three Curve Series. The dates and the times of day indicated on here are such that the particular time chosen may be checked by you, if you care to do that.

Q. Now, as I understand it, Mr. Souther, would check over a day, go over one day, for instance November 1st, 1907, and he would find a well marked change, perhaps a crest at Buffalo. Then the same day he would look at the gage readings for the Suspension Bridge, wouldn't he?

A. Yes.

Q. And if he found a crest there, he would put that down, would he, is that right?

A. That is—

Q. Without regard to the time when the crest appeared at Suspension Bridge, as compared with the Buffalo gage?

A. Yes.

Q. And as a matter of fact, the crest at Suspension Bridge

might have been due to some fluctuation or rise of the Buffalo gage the day before, might it not?

A. No. If you will refer to this Three Curve Series, you will see that the curves are very characteristic.

Q. I am trying to ascertain how Mr. Souther got at those figures.

A. I will be very glad to explain everything I can.

Q. I am trying to get at it. If you will just answer my questions I think we will get along. If, for instance, on November 1st, 1907, there was a crest at Buffalo at 1.00 A. M., and there was a crest at Suspension Bridge at 1:00 A. M., and that was the only crest appearing at the Suspension Bridge for that day, you would not say that the crest at 1:00 A. M. at the Suspension Bridge was due to any crest which he had observed for that day at Buffalo at the same time, would you?

A. These things are sufficiently characteristic, so that the relation—

Q. Will you answer my question? Would you expect that?

A. Won't you please read the question?

Q. (Question read.)

A. If these two corresponded, that would be set down as an observation, if they were well marked.

Q. Set down as zero?

A. As zero.

Q. If you will answer my question, would you say that the crest observed at Suspension Bridge was due to the change of elevation or the crest, which was shown at 1:00 A. M., the same hour, at Buffalo?

A. I should say it was due to the error of observation.

Q. Might it not have been due entirely to a crest appearing at Buffalo the preceding day?

A. No.

Q. Why not?

A. Because the relation is so definitely established. And I refer you again to the Three Curve Series on this point. The relation is so definitely established that we know definitely, and as stated by your own witnesses in this case, Mr. Freeman among others,—

Q. But, Mr. Shenehon, the crest at Suspension Bridge, was not due to any crest at Buffalo that same day, was it?

A. It contains what is known as the error of observation. That is the same error that makes another observations 7 hours, another one 6.

Let us give you an illustration in this case, where a similar rejection was made by Mr. Stearns in his physical analysis,

in which he finds the years 1895—6 abnormal, because there was less water in those years.

Mr. Hopkins: I think if you read the question again, the matter you have in mind is not involved in it. He assumes those things as absolute, not as observations.

Mr. Adcock: There is a zero here—

Mr. Hopkins: They are not taken as observations but as absolute facts.

Mr. Adcock: No.

The Witness: These are observations that must be understood to be subject to the error of observations. I have I think explained that as fully as I can.

Mr. Adcock: All right, we will go ahead. I think we understand your position. (Q.) Now, what time in your opinion does it take a crest or change of elevation at Suspension Bridge to appear at the Whirlpool?

A. Well, a very few minutes later, according to the observations.

Q. How many minutes?

A. The indications here are for 3 hours and 6 minutes, Suspension Bridge; 3 hours and 9 minutes at the Whirlpool.

Q. That would be about three minutes afterwards, wouldn't it?

A. Yes, that is for the marked high. For the marked low it is 3.18 at Suspension Bridge and 3.26 at the Whirlpool. That is a difference of eight minutes. Eight and three are eleven; about six minutes appears to be the time.

Q. Now, Mr. Shenehon, will you examine sheets number 1, 2, 3, 4 and 5, of the papers which you produced this morning entitled: "United States vs. Sanitary District of Chicago, determination of lag between Buffalo and Whirlpool gages, time required for change in Lake Erie to reach Whirlpool. Only days of well marked changes used in determination." Now will you refer Mr. Shenehon to the first sheet, the October 1st, 1907, data. You find in the column marked lag, hours, with reference to well marked high water at Buffalo, Whirlpool, you find that the lag between Buffalo and Suspension Bridge is two hours, do you not?

A. Yes.

Q. The first observation sheet 1?

A. Yes, for Suspension Bridge, the lag for the first observation—

Q. Is two hours?

A. Is two hours.

Q. And for the Whirlpool is what?

A. Three.

Q. Three hours for the same days and the same lag is it not?

A. Yes. You will note on this these are even hours, and with the exception of the fact that the half is sometimes put in, it is difficult to determine where the particular peak was. The peak is not always sharply defined, you understand.

Q. We will go along. Do you think it physically possible that the lag should have been an hour between the Suspension Bridge and Whirlpool?

A. That is not so indicated there. The error of observation enters there, individual observations.

Q. What is this error of observations?

A. Where you are taking the nearest hour on these observations, and simply getting your data from a sheet in which the hourly ordinates are scaled, it does not follow at all that—the individual minutes not appearing—the difference should be in smaller units than hours.

Q. Take the one on the 2nd of October, there was a difference there of an hour, wasn't there, as shown there for October 1st?

A. Yes.

Q. Between Whirlpool and Suspension Bridge?

A. Whirlpool shows 1 hour later.

Q. For October 2nd, it is two hours to the Suspension Bridge and two hours to the Whirlpool, is it not?

A. Yes.

Q. That is another error of observation, isn't it?

A. Yes.

Q. And on the 3rd, it was two hours and a half to the Suspension Bridge and two hours to the Whirlpool wasn't it?

A. Yes.

Q. That was the travel of the crest?

A. You are—

Q. In other words the crest got to the Whirlpool a half an hour before it got to the Suspension Bridge, didn't it?

A. After you take care of the error of observation, the absolute fact is not inconsistent. The error of observation is sufficient to take care of this burden, because we are taking these out from hourly scalings.

Q. Let us take the next, October 5: The lag to Suspension Bridge was three hours, wasn't it, and to the Whirlpool was half an hour later, three hours and a half?

A. Yes.

Q. And on the 6th, it was two hours to the Suspension Bridge and three hours to the Whirlpool?

A. Yes.

Q. Making a difference of an hour?

A. Yes.

Q. The 7th, it was one hour to the Suspension Bridge and two hours to the Whirlpool, wasn't it?

A. Yes.

Q. An hour later at the Whirlpool, which you say takes about three minutes?

A. No.

Q. Six minutes?

A. Takes about six minutes.

Q. On the 8th, the lag to the Suspension Bridge was 5 hours and a half, wasn't it?

A. Yes, that is the observation.

Q. And 4 hours to the Whirlpool?

A. Yes.

Q. An hour and a half difference?

A. Yes.

Q. In other words it got to the Whirlpool an hour and a half before it got to the Suspension Bridge.

A. I think you are ignoring the fact that you have not a sharp, stacatto point in which you pick out a particular clear cut thing, and the error of observation I have mentioned already must be borne in mind by you.

Q. It would be hardly reasonable to expect that the crest would travel to the Whirlpool an hour and a half quicker than it would travel to the Suspension Bridge?

A. No, that fact is not indicated by the observation.

Q. It is not indicated?

A. Not when you take into account the error of observation, the fact that you are dealing with a quantity where you must pick out by judgment what is the crest of a rounded point, where several hours may be nearly the same.

Q. Then you do not mean error of observation entirely?

A. Yes.

Q. Don't you mean error of judgment?

A. That is a part of the error of observation always.

Q. So that you refer also to the error of reading the gage, do you?

A. No.

Q. And the error of judgment of the man who is picking out these various crests and valleys and so forth, is that it?

A. That does enter in this. As I have stated already, the crest at a particular time may not be represented by a sharp clearcut point.

Q. Wouldn't you think a man had committed a very serious blunder if he had assumed that the change in elevation at Buffalo would be shown at the Whirlpool an hour and a half quicker than it would be at the Suspension Bridge?

A. I should say he was honest, using very honest methods in his determination, setting these things down as they appear, and that there is no accumulating error in the thing; it is eliminated by the two hundred and odd observations we have in getting the lag.

Q. In other words you go out and you get anything, and because you get a great number, you think that any error would be eliminated?

A. No, I take exception to you going out and getting anything that is not within well defined limits.

Q. Take for instance the 10th, the lag for Suspension Bridge was four hours and for Whirlpool was four hours, wasn't it?

A. Yes. When I say the lag, what is set down here as the even hour, representing the nearest hour; ordinarily the half hour is used where it seemed to be an even thing between the two hours.

Q. Should they have used any half hours at all?

A. The half hour is the least unit used in here, in any place.

Q. Then the time error could not be more than 30 minutes in any instance?

A. That does not follow.

Q. Take the 11th, you have the lag to the Suspension Bridge 2½ hours and to the Whirlpool 3 hours?

A. The 11th?

Q. Yes?

A. Two hours and a half to Suspension Bridge and Three hours to the Whirlpool.

Q. On the same day at the 19th hour, you have one hour at Suspension Bridge and two hours and the Whirlpool, do you not?

A. Yes.

Q. Might not the peak which is indicated at Buffalo at 13 o'clock, correspond to the peak at the Whirlpool at 21 o'clock? That is seven hours.

A. I think a reference to the Three Curve Series would be illuminating on that point.

Q. We will endeavor to illuminate the Three Curve Series at the proper time, Mr. Shenehon.

A. All right.

Q. Take the 12th, you have the lag to the Suspension Bridge two hours, and the Whirlpool three hours, haven't you?

A. Yes.

Q. And on the 13th you have the lag at the Suspension Bridge three hours, and it appeared at the Whirlpool two hours later, five hours is that right?

A. Those are the figures indicated.

Q. And on the 14th, you have another instance where it is two hours, don't you, at the Suspension Bridge, and three hours at the Whirlpool?

A. Yes.

Q. And on the 15th, it appeared an hour earlier at the Whirlpool, which is three hours lag than it did at the Suspension Bridge which was two hours, is that right?

A. That is the indication by the observations.

Q. Take the 21st, it was two hours at both places, wasn't it?

A. Yes.

Q. And on the 26th it appeared at the Whirlpool in four hours, or one hour earlier than it did at the Suspension Bridge, which was five hours, is that right?

A. Suspension Bridge indicated five and Whirlpool four.

Q. And on the 30th, it appeared at the Whirlpool an hour earlier than it did at the Suspension Bridge, four hours at the Whirlpool and five hours at the Suspension Bridge, is that right?

A. Five hours Suspension Bridge, four hours Whirlpool is indicated on this sheet.

Q. And on the 31st it appeared two hours earlier at the Whirlpool than it did at the Suspension Bridge?

A. That is the indication.

Q. Three hours at the Whirlpool and five hours at the Suspension Bridge, is that right?

A. That is the indication

Q. On the 15th, the falling stage, it was five hours to the Suspension Bridge and four hours to the Whirlpool, wasn't it?

A. Yes, that is the indication on the sheet.

Q. On the 11th, Mr. Shenehon, it took an hour to get to the Whirlpool, and it got to the Suspension Bridge in no time, instantaneous change, is that right?

A. No, you do not mean it got there, you mean the error—

Q. The indication shows that.

A. The time it got there less the error of observation is zero, as indicated by the sheet?

Q. The observations show similar conditions all the way through, do they not, as to what I have stated here?

A. You mean that individual observations will show discrepancies?

Q. Discrepancies of the character which I have mentioned?

A. Yes, you would expect them to, the nature of the observations is such.

Q. Several hundred, or two hundred per cent. sometimes, is that right?

A. I think to express it in percentages is distorting the truth.

Q. You like to express some things in percentages, don't you, for instance ½ of 1 per cent. being the error of discharge and so forth?

A. In this case, you take a short base with a relatively large error of observations, it sounds very large when you state it in percentage.

Adjourned to Saturday, May 16th, 1914, 9:30 A. M.

Saturday, May 16, 1914, 9:30 A. M.

FRANCIS C. SHENEHON resumed the stand and testified further on cross-examination as follows:

Mr. Adcock: Q. Suppose that in the case of the St. Clair River referred to on Tuesday the discharges for two elevations were 203,382 cubic feet per second and 187,082 cubic feet per second respectively, and suppose that the lower discharge was too small, and in error one per cent. and the upper discharge was also too small and in error .902 of 1 per cent., what would be the difference of their corrected discharges?

A. The differences in those two cases are substantially the same, the difference of the former quantities given being 16,300 cubic feet; subtracting the error from each of these quantities, the resulting difference as I make it is 16,340.

Q. Cubic feet per second?

A. Cubic second feet.

Q. What is the difference of the original discharges, the same, wasn't it?

A. 16,300; I gave that.

Q. Then on Wednesday, Mr. Shenehon, when you said the range of error of the difference of these discharges was from 1 to 25 per cent., you were in error weren't you?

A. The range would be from plus an error 25 per cent. to minus 25, and may be anywhere within those limits, and therefore passes through zero.

Q. It would be a more correct statement to say it would be from zero to 25 per cent.?

A. Well, between plus 25 and minus 25 of course includes that. Your statement here, however, does not quite cover that case because you have not taken 1 per cent. error in each of the quantities. You have .9 of 1 per cent. in one case and 1 per cent. in the other.

If you make each one 1 per cent., which was the proposition as I understood it when discussing it before, this would show an error of 1 per cent. in the increment, assuming that the 16,300 is an increment.

Q. Would the error be from 1 to 25 per cent., or from zero to 25 per cent.?

A. Well, under the assumption here, assuming 1 per cent. error and on the same side, it would be 1 per cent. of error. If you were assuming it to be plus, it would be 1 per cent. in error on the upper side, on the large side. If you assumed it to be minus, it would be 1 per cent. in error on the lower side. But in the range of possibility, we have all the way from the extreme plus quantity to the extreme minus. Of course in passing between there, it would pass through the value zero. I think that is the point you have in mind.

Q. Yes? If the change of elevation was .57 feet, what would be the percentage of error of the increment, zero to 25 per cent.?

A. Please read that question.

Q. (Question read.)

A. Yes. Having gotten a percentage of error in the increment from a difference in this way, dividing by that it is independent of the range after you once reach that conclusion, as I explained in my testimony the other day.

The littleness of the difference between two quantities, where the range is small, is large in proportion to the error of the volume of flow concerned; and that is the thing that makes the error in the increment dependent on the range, as it is.

Q. Referring to the report of the Chief of Engineers for 1912, Table Number 1, page 3546, do you accept the figures

there given as correctly representing the discharge of the St. Clair River?

A. I have never checked those figures.

Q. What is that?

A. I have never checked these figures; I so stated in my testimony, that my conclusions in regard to the St. Clair River are dependent on the testimony of the men of the Lake Survey in whom I have confidence, and does not depend on an individual or detailed examination of the later conclusions, or an analysis of the later observations.

Q. Then we are to understand, I assume, that the testimony you have given with reference to the discharge of the St. Clair River is based entirely on the testimony of the men of the Lake Survey who have testified in this case?

A. Yes. Originally it is based on confidence in Mr. L. C. Sabin, and upon knowledge of his good judgment and careful observing. The later conclusions are based on the observations of Mr. Richmond and Mr. Moore, and of the conclusions and computations made by them, as well as Mr. Ray, principal assistant engineer of the United States Lake Survey. And my testimony in this respect simply reflects my confidence in these men.

Q. The fact that you have testified, then, with reference to the discharge of the St. Clair River, is to be taken rather as a commendation of their work by you, is it not?

A. Yes, of their work as observers, and their careful studies and reductions, and so far as the later increment of the St. Lawrence is concerned, the same reservations were put in my testimony.

Q. Of course the St. Lawrence was a little bit different. There you had made measurements yourself on that river?

A. Yes. I am speaking of the later measurements and the later conclusions on the St. Lawrence with the new condition of the river after the building of the Gut Dam.

Q. I understand you have not measured the St. Clair River?

A. Oh, yes, I was in charge of the original measurements.

Q. I said the St. Clair?

A. You say I personally?

Q. Yes?

A. The work at the Gorge Section was initiated while I was Principal Assistant Engineer.

Q. But you did not have personal charge of the work?

A. I was in general supervision of the office, and directed the choice of a section there. I did not very largely super-

vise either the observations in the field or the reductions. I did not visit the work.

Q. Those were the measurements in what year?

A. 1908.

Q. I think you have explained why you were willing to take some of the conclusions which were reached by Mr. Moore and Mr. Richmond with reference to the St. Lawrence, in your previous testimony didn't you, on cross-examination?

A. Yes.

Q. These measurements showed a different increment than your earlier measurements did?

A. Yes, a change having taken place, you understand, in the regimen of the St. Lawrence river between those times; that is the building of the Gut Dam, introducing a new condition.

Q. I think you have stated the effect of the Gut Dam upon the increment to be 5½ per cent., is that right?

A. Yes, that was my estimate of the change.

Q. Does the difference between consecutive numbers on horizontal lines represent the back water effect of Lake St. Clair for the .1 foot changes in its elevation?

A. I so understand it, yes.

Q. At the International Bridge Section, what meter was used to traverse the vertical?

A. Meter L. S. 2 B.

Q. What is that?

A. L. S. 2 B. for the observations of the United States Lake Survey.

Q. The L. S. is a new term used here?

A. That is Lake Survey 2 B.

Q. That was not the Haskell meter?

A. Yes, the particular meter—

Q. I didn't know but what we had a new name for it now?

A. No, I think you will find in the tabulations—

Q. That is the number of the meter?

A. I refer to the summary of discharges table number 1, of F. C. Shenehon, Assistant Engineers, 1906. The rating number was meter L. S. 2 B, meter L. S. 4 A.

Q. What does the 2 mean?

A. That is the type of the meter.

Q. Is that the type or the number? B is the type and 2 is the number of the meter in your equipment, isn't it?

A. Yes, B is the type and 2 is simply the one in our equipment.

Q. That is you give it a number in your office, don't you?

A. Yes, these numbers as I recollect it were stamped on the meters when received. That is with a metallic stamp on the lead as I recollect of the meter.

Q. How close together were the two meters run in the Niagara River work, when the traversing meter was checking with the index meter?

A. Three to four feet.

Q. What is your opinion as to the relative accuracy with which the flow of large and small streams can be measured, say streams of 200,000 cubic feet per second, and streams of two to ten per cent. as much?

A. I should say the percentage precision of the larger stream is somewhat greater, although you have reached a point now where there is not a large difference. A canal flowing 10,000 cubic second feet, as I stated, should be within 2 per cent. if very carefully gaged, and a stream of 20,000 might have a little better precision than that.

Q. Don't you claim a great deal better precision in your measurements of the Niagara River, about ½ of 1 per cent. of the discharge, something like that?

A. Within 1 per cent. is my conclusion as to the precision.

Q. I was under the impression some of the other witnesses connected with the Lake Survey gave it as half of one per cent., didn't they?

A. Yes 1 per cent. is my figure.

Q. But they had a figure of ½ of 1 per cent., about?

A. Yes.

Q. Then you don't agree with their figure?

A. Within the limits stated by you, that appears to be the fact.

Q. Just why do you differ?

A. I per cent. is my judgment of the precision of the work.

Q. I wondered if you had any reason, or was it just a kind of feeling you had. You know you engineers have feelings with reference to certain things?

A. Oh, it is better than that. I think possibly it was originally derived from the agreement between the Open Section and the Bridge Section on the Niagara River. And this is further strengthened by the agreement of the Third or Split Section; and it is further strengthened by the agreement of sections on the St. Clair.

Q. I am trying to get an understanding why you think those measurements are so accurate?

A. You understand, the man who feels that the precision, or has reached the conclusion that the precision is ½ of 1 per cent. may be right and I may be in error. I am simply giving my judgment in the matter.

Q. Well, what I was trying to get at is why you differ from Mr. Richmond and Mr. Moore. You are more or less responsible for the conquering of the Niagara, and I wondered just why these men who were under you felt that the work was better than you felt it was?

A. I can't help you in your explanation.

Q. These discrepancies and so forth are somewhat confusing, and I would like to get your opinion as to why you say 1 per cent. and they say ½ of 1 per cent.?

A. I think possibly the term "error" is stated in different ways. Mr. Hayford, for instance, gave ½ of 1 per cent., as I recollect, as the probable error of the volume of flow.

Q. What did he state?

A. My recollection is ½ of 1 per cent. I can confirm that (referring to memoranda) yes, the probable error as derived by Mr. Hayford for the volume of flow is ½ of 1 per cent. And he concluded that it is practically certain that the error cannot exceed 2½ per cent., but what is stated there, is I suppose, the reason why we differ; not a statement of this particular thing. The one per cent. that I speak of is not the mathematical probable error. It is a judgment—

Q. You had formed your conclusion as to the probable error there before Mr. Hayford had solved this mathematical problem, hadn't you?

A. Yes, my statement was in the earlier testimony in 1909.

Q. And his conclusions there were simply the results of mathematical computations, weren't they?

A. In part. He investigated pretty fully the methods and processes used, the checks, the rating of current meters, the various conditions, by looking into the literature on the subject, so while the ½ per cent. is a probable error, that is a mathematical quantity. The maximum error stated contains his judgment, as well, as I understand it, based on examination of all the elements entering into the case.

Q. Then this 1 per cent. of error which you say there may be in the increments, the volume of discharge determined, is the result of your judgment, is it?

A. Yes, that is true. You understand—

Q. You could not give any particular reason for it?

A. You understand with figures before me—for instance

a long line of plotted observations indicating for the most part a precision within 1 per cent., or two per cent. in the individual observations, the accord of the observations among themselves, the knowledge I have of the care with which all processes were scrutinized and carried out, and the check of independent sections, these things of course have all come in to help me reach a conclusion as to what I regard as the precision of 1 per cent. When I say that, you understand the Split Section had not been gaged at the time I made my original statement in 1909.

Q. You haven't changed it now, have you?

A. No. I should not wish to say that we reached a precision higher than 1 per cent., that is in my judgment. The probable error shows a little higher than that, but my judgment is there ought to be a leeway there of ½ of 1 per cent.

Q. These people who surely do not know as much about the gaging of the Niagara as you do have reached apparently reached the conclusion that the work was closer than you have yourself?

A. Mr. Hayford, with my explanation here—

Q. I am speaking of Mr. Ray and Mr. Moore.

Mr. Hopkins: Objected to.

Q. Mr. Richmond?

A. I should wish to refer to their testimony. I do not understand that they—

Q. Then you don't know whether they stated the precision was within ½ of 1 per cent.?

A. I am of the opinion that Mr. Ray didn't make that statement. I should wish to refer to the testimony.

Q. Perhaps Mr. Moore or Mr. Richmond did?

A. I should wish to refer to their testimony.

Q. Would you be surprised if you should find in the testimony that they had stated that it was within ½ of 1 per cent.?

A. I should be surprised if I found Mr. Ray had made that statement.

Q. You think he is more conservative than Mr. Richmond or Mr. Moore or both of them, do you? Is that the reason that you would be surprised?

A. I should wish to read the testimony before answering that question to refresh my memory as to the exact way in which they made their statement.

Q. I know, but you say you would be surprised if Mr. Ray made the statement, implying you would not be surprised if Mr. Moore or Mr. Richmond stated it?

A. I had in mind that Mr. Ray stated two per cent. I may be in error about that.

Q. I am asking you why you would be surprised?

A. A matter of memory.

Q. Entirely?

A. Yes.

Q. Not because of your judgment of the men?

A. No, I should not in these matters prefer Mr. Ray's judgment to my own.

Q. But between Mr. Moore, Mr. Richmond and Mr. Ray?

Mr. Hopkins: I object to the question. He cannot know what other people know. It is entirely unfair; it is incompetent for one man to tell in this sort of a situation what the ability and competency of another man is.

Mr. Adcock: Q. I am asking you why you would be surprised; why you state you would be surprised if you should find that Mr. Ray stated that?

Mr. Hopkins: Objected to further,—

Mr. Adcock: Q. Had made the statement that it was 1 per cent.?

Mr. Hopkins: Objected to.

Mr. Adcock: The error was 1 per cent.

A. May I refer to the testimony.

Q. Implying you would not be surprised if Mr. Moore or Mr. Richmond had made the statement.

Mr. Hopkins: I object further to the question as having been answered.

A. It is dependent on my recollection of the testimony.

Q. Only?

A. Yes. I think we ought to spread out this testimony in front of us, so that a witness may refer to matters coming up. The testimony is so voluminous that I do not carry in mind every figure that has been stated by a witness.

Q. Mr. Ray did say 2 per cent., Mr. Shenehon, page 2276?

A. Referring to the testimony of Mr. Ray on page 2276 of the testimony in manuscript (printed record, page 2791) I find that he makes the following statement:

"From my knowledge, I judge the hydraulic work on these three rivers to be probably the most accurate measurements in large streams that have ever been done. The precision of measurement considering the weight mean observations I believe to be within 2 per cent. of the exact result." He is there, of course, speaking of all three rivers.

Q. On page 2331, Mr. Moore stated: "For the Niagara, probably within ½ of 1 per cent."

A. You are referring to the Canal of the Niagara Falls Power Company.

Q. No, the Niagara River?

A. Mr. Moore's statement there is what is known as the probable error for the Niagara River, ½ of 1 per cent., agreeing with Mr. Hayford on that.

Q. Then you do not agree with either Mr. Ray or Mr. Moore on that?

A. The mathematical probable error is in the vicinity of ½ of 1 per cent. I allow myself a leeway of half of a per cent. for the possible constant errors that may enter, that are not eliminated in discussing the probable error.

Q. He says: "For the Niagara discharge probably within ½ of 1 per cent.?"

A. Yes. My statement of 1 per cent. has a little more to do with a nearer certainty rather than the probable error.

Q. You differ with both of them then?

A. No, the probable error is about ½ of 1 per cent.

Q. Mr. Ray stated it was within 2 per cent.?

A. He does not give that as the probable error. You are confusing the mathematical term "probable error" with the errors of a man's judgment, and that appears to be Mr. Ray's.

Q. You think Mr. Moore did not give his judgment then, just simply the mathematical probable error?

A. Yes, that appears that way. It is an even thing whether it is better than ½ of 1 per cent., or not quite as good. That is what probable error means.

Q. You spoke of the relative accuracy with which certain streams of different sizes could be measured, and you stated that a stream of 5,000 cubic feet per second could not be measured as accurately as one of 2,000 cubic feet per second?

A. That is other things being equal.

Q. Yes, I think that would be a general statement. How about one 2 per cent. of the larger stream, say 4,000 cubic feet per second?

A. In the vicinity of 2 per cent.

Q. Error?

A. Yes.

Q. Your judgment is that the error would be twice as great in the smaller stream than in the large stream that was mentioned?

A. Yes, it might be. That is, that was a conclusion I reached at the time we gaged the power canals at Niagara Falls; we might have an error as big as 2 per cent.

Q. Upon what grounds do you base your conclusion in that regard?

A. Of course there are quite a number of elements, but a large stream is the summation of a series of small streams. The 2 per cent. I speak of might be the error, it might be plus or it might be minus. When you sum up a number of small streams, as, for instance, you take the International Bridge as an illustration, there we have divided up the whole river into nine spans, if you wish to consider them that way, or 21 stations. Each of these stations, each of these small streams may have an error of 2 or 3 per cent., but the aggregate percentage of precision is much better than the precision of the individual small streams or stations. That is a principle coming in. That is one of the elements. The other one is of course in a deep stream like the Open Section of the Niagara River or the Bridge Section of the Niagara or the Third Section, or the Three Point Section of the St. Lawrence, or the two sections on the St. Clair you can determine very definitely the trend of your vertical curve where you could not do that with the same instruments in a shallow stream.

Then there is the relation also between the wetted perimeter and the cross sectional area, that needs some consideration.

Q. Does this apply, in your judgment, to a comparison of your gagings of the Niagara and the gagings of the Chicago River or the Drainage Canal?

A. Yes, I think the Chicago River was gaged, I believe I said within 2 per cent., or maybe that is the canal at Lemont, is what I have in mind.

Q. You stated that one reason why a small stream could not be measured as accurately as a large stream was because of the greater percentage of unexplored regions, did you not?

A. No, that is not quite a—I didn't use quite those words. I guess it amounts to about the same thing.

Q. Practically the same thing?

A. That is there are certain portions of the cross sectional area where your transverse curve or your vertical curve is changing very rapidly, that you cannot explore with your larger instruments in your smaller canal. I refer to the case of the canal at Cornell.

Q. How about the Drainage Canal or the Chicago River, a stream of 4 or 5 or 6,000 cubic feet per second?

A. The conditions there with the greater depth and the smooth sides represent fairly good conditions for gaging.

Q. Do you think they are as good as at the Bridge Section of the Niagara?

A. As I understand the conditions there in the section at Lemont, without having visited it, I should say the condition is better. Regarded as a single stream, it is better than the side streams, at least, in the Niagara River at the Bridge Section.

Q. Considering the whole Niagara River?

A. Oh, no; I adhere to and believe absolutely that a statement of 1 per cent. for the Niagara River is my judgment as to the precision obtained.

Q. And 2 per cent. for the canal?

A. Yes, that is a rough judgment, that 2 per cent.?

Q. Then that is based upon a greater portion of the regions near the walls of the canal and along the bottom that you mentioned?

A. Yes, you ought to get your transverse curve and your vertical curve very accurately in the Drainage Canal.

Q. You do not think you could measure the flow of the Drainage Canal as accurately as you could the Niagara River?

A. If we had the whole outflow of the Great Lakes such as we have at Buffalo through twenty drainage canals of the, same dimensions and smoothness, we could probably measure with an equal precision.

Q. Considering simply the one by itself?

A. I have made my statement that 2 per cent. is about my judgment of the precision which we may secure.

Q. You stated that the section at Lemont on the Drainage Canal was better than the Bridge Section of the Niagara River, did you not?

A. It is better than some stations. That was my statement.

Q. But that on the other sections, the Open Section and the Split Section, you thought they were better than the Drainage Canal, didn't you?

A. Are you referring to individual stations?

Q. No?

A. Or to the aggregate?

Q. The aggregate?

A. You understand the aggregate, the sum total of volume of flow in the Bridge Section I believe to be better than the measurement on a single Drainage Canal at Lemont. That is clear, isn't it?

Q. But take the Bridge Section as a whole, how does it compare with the Section on the Drainage Canal?

A. Well, we have a number of stations, 21 in all. Each one has an error probably bigger than the two per cent. mentioned. When I say "all" not all of them, the mid-stream sections in spans 4, 5 and 6, probably have a better precision than the Drainage Canal, better than 2 per cent. individually.

Q. In view of the fact that the Split Section and the Open Section agree so well, as you say, with the Bridge Section, does that change your opinion any as to your comparisons with the three sections?

A. Oh no, no indeed.

Q. Take the Bridge Section altogether, it is a better section than the section at Lemont on the Drainage Canal, and the error of the Bridge Section would be half as much as that of the Drainage Canal?

A. Let me state that a little differently. If you should measure the volume of flow in the Drainage Canal in twenty different sections, or in a number of sections, you will get a precision higher than 2 per cent. on the Drainage Canal. So it is the aggregation of the number of measurements, the number of sections, where one may be a little large and the other may be a little small, and in the end the sum total has a precision higher than any one of them on the average section. That is the principle that enters in this matter, and is one of the reasons why we do get this high precision in the river measurements.

Q. The larger the river the greater the precision?

A. Yes. Just think of a mid stream section at the bridge, for instance, say the middle of span 4. Here is a considerable volume of water with a water perimeter on either side, if I may so speak of the 80 foot section, and simply the friction of the bottom, it has not the friction on the sides the same as your canal, so there is a condition that is very excellent and that is the condition we have in open river sections, a series of smaller streams flowing side by side. The error in one may be that it is a little too big and the error in the other a little small, and in the end the aggregate, balancing error against error, gives us a high precision such as we have shown in our triple gaging on the Niagara River and our triple gaging of the St. Clair River.

Q. That is because of the greater proportion of unexplored regions in the one, isn't it, than the other?

A. The unexplored region needs to be thought of as that region where you have sharp changes, as towards the bottom

or towards the side of the canal; or towards the bridge piers, in the case of the International Bridge.

Q. Which do you consider the more accurate, the Bridge or Open Section gaging of the Niagara?

A. The conditions at the Open Section are a little better than those at the Bridge Section, in my judgment.

Q. Which is the more accurate gaging?

A. A conclusion ought to be a little more accurate for the Open Section than for the Bridge Section; and yet the precision indicated by me has to do with the conclusion reached by the two, you understand. These two sections checked within 1.3 per cent.

Q. Take the Bridge Section alone, what percentage of error is there there?

A. You understand it is difficult to assign with the great exactitude which you would like to have me, the percentage of error.

Q. No, I do not agree with you on that. I am just trying to find out what you believe to be the percentage of error of the Bridge Section gagings, alone.

A. You understand my judgment of the precision depends to some extent on the agreement of sections; the agreement of the several gagings in the same river.

Q. Then if you did not have a section to compare with the Bridge Section, you would not know just what percentage of error to ascribe to that?

A. The analysis of the elements entering indicates that the precision must be very high.

Q. Then without considering the Open Section gagings at all, what do you say?

A. Of course it is difficult for me to answer that question, because I have in mind the various duplicate sections and triplicate sections that have been measured, and that has doubtless influenced my judgment in this matter.

Q. How close to the bottom were the velocities examined at the Bridge Section?

A. My recollection is about 18 inches.

Q. How close to the piers at the sides?

A. Within one to two feet.

Q. What proportion does the unexplored area at the Bridge Section adjacent to the bottom and the piers bear to the total area?

A. I would have to make a computation to determine that; and I would like to know what you mean by unexplored. You mean below that foot and a half, 18 inches at the bottom?

Q. Yes?
A. And within say the two feet?
Q. Yes? Did you get always right up to within two feet of the piers at the sides?
A. That is my recollection. The figures however will show that in detail.
Q. As a matter of fact, weren't you between two and six feet?
A. Well, I would have to follow that—
Q. Never less than two and sometimes as high as six?
A. It would depend on circumstances I think, in the particular case.
Q. I am asking you simply for the purpose of refreshing your recollection?
A. Yes.
Q. And directing your attention to that particular thing?
A. Yes. I may have figures by which that can be determined. I will be very glad to refer to them. You understand it is 15 years ago since these gagings were made, and my recollection may be a little dim on certain points.
Q. Of course it is not very long ago since you expressed an opinion as to the accuracy of the measurements there, and I assumed that perhaps you had all those things in mind?
A. No, that opinion was expressed in 1909.
Q. You still have an opinion with reference to it, stated I believe recently?
A. Yes, my recollection is that we in detail and in generalization throughout scrutinized the work and secured the results of the highest precision.
Q. Your opinion now then is based upon your remembrance of the conclusions that you reached then?
A. I have read some documents recently, the letter which I wrote to Mr. Haskell, and some other things that—
Q. I am referring Mr. Shenehon to your own individual ideas of the work that was done there. As I understand you did make most of those gagings?
A. Yes, I was in charge.
Q. Made most of the gagings?
A. Directed the gagings and made many analyses of the various points where error might enter.
Q. And your conclusion now is based upon your remembrance of the conclusion you gave in 1909, with reference to the percentage of error?
A. In part. Of course I have had this much under con-

sideration since. This case has rather brought up a great many things but in such matters as you refer to, whether I got two feet from the pier or four feet or six feet, that is a matter I need to refresh my memory on.

Q. When you gave your opinion recently as to the 1 per cent. of error there, you did not have in mind how close you were to the piers on the sides, you didn't have that in mind distinctly?

A. No, because it would not make any difference in the conclusion. I did have in mind however the corroboration of the various sections as indicated in my testimony, that have been made since then.

Q. You might make that computation with reference to what proportion of the unexplored area at the Bridge Section adjacent to the bottom and the piers, what proportion that bears to the total area?

A. Taking a value of two feet from the Bridge pier, and a foot and a half from the bottom, I get 2800 square feet. And at elevation 568, this corresponds to a little less than seven per cent., we will call it seven per cent. of the cross sectional area.

Q. How does this compare with the Chicago River, say at Loomis Street, where the width is 200 feet and the sides are practically vertical for 12 feet below the water line, when the bottom gradually slopes to a depth of 26 feet in 60 and 70 feet of width, and is practically level for 70 feet in the mid-channel, the area being about 4300 square feet?

A. I make the indeterminate area, as I believe we have before referred to this in the Chicago Drainage Canal—

Q. I am referring to a particular section.

A. In this particular section handed me, I make the indeterminate area 353 square feet in a cross sectional area of 4300, which is 8.2 per cent.

Q. Would an accurate, a closer computation of the Niagara, bring that percentage up to about 7½ per cent.?

A. The computation made by me is a little crude. There was some scaling in the computation, and I made it 6.8 and called it 7 per cent., because Mr. Williams' assistant makes it 7.4. I think 7 per cent. is a fair statement of the case. It does not make much difference, however.

Q. Then there is no special credence to be given to the Bridge Section measurements in comparison with, say a section on the Chicago River such as has been described, on account of the size of the section?

A. If we had twenty, the volume of flow of the Great Lakes flowing in twenty of these channels we would have the precision a little bit higher than the Bridge Section.

Q. But the percentage of unexplored area was equal?

A. Yes.

Q. In the Bridge Section and in the section of the Chicago River which has just been described, there is very little difference?

A. Yes, I should say in this unexplored area, as we have called the indeterminate area, about three per cent. of the flow of the river passes.

Q. What was the difference between the section as adopted by you and that used by the Board of Engineers on Deep Waterways?

A. Cross sectional area?

Q. Yes?

A. My recollection is that the Board of Engineers made it about three per cent. greater.

Q. That would give a greater volume of water then, wouldn't it, passing?

A. Yes, that would indicate a greater volume of water.

Q. How far would the position of the meter used in traversing the vertical be down-stream from the plane of the edge of the guard rail of the Bridge.

A. An endeavor was made to bring it practically under the guard rail, or a little bit below.

Q. How was it prevented from drifting?

A. A tackle was arranged in which an 80 pound weight was suspended with a pulley, over which the cable of the meter passed, or a snatch block, I guess is a more accurate term. Then the cable was pulled up-stream from the upper side of the bridge, from the upper chord of the bridge—not the chord, the outside member.

Q. Could you make a sketch on a piece of paper there which would show how you maintained the meter on the section?

A. Do you wish to put this in evidence?

Q. I do not know whether we will or not? Just a rough sketch.

A. (Witness makes sketch as directed.)

Q. How far up-stream was the cable drawn at the point of entering the water?

A. My recollection is 10 or 12 feet. That is for the extreme condition in span 3, the deep span.

Q. That is where it was deep and the water was swift?

A. Yes, that was computed for each position.

Q. You suspended your meter at the lower side of the bridge didn't you?

A. Yes, the North side which is the down-stream side.

Q. Down-stream side?

A. Of the bridge, yes, so the bridge itself forms a platform which may be utilized and was utilized.

Q. At a depth of 10 feet below the surface, how far down-stream from the guard rail would the meter be?

A. Substantially under the guard rail, perhaps a few feet down-stream, two or three feet.

Q. How many feet?

A. I can't give a statement of this.

Q. Approximately?

A. I do not care to approximate that. If you wish to give me half a day to make computations on that, I presume I could give you some statement that would be—

Q. Then you haven't any recollection at all as to that?

A. My recollection is that we placed the meter definitely through the vertical plane.

Q. And at 15 feet depth the same thing?

A. I make the same statement.

Q. 20 feet, 30 feet, 40 feet and 50 feet?

A. I do not wish to make any statements concerning the —you are speaking now, if the meter were free and not pulled up-stream?

Q. No, the position where it actually was during the gaging when you occupied a section.

A. Making a measurement of the discharge?

Q. The vertical?

A. Or taking a vertical curve?

Q. Taking a vertical curve?

A. The vertical curve in the swift water, tackle was used by the United States Lake Survey as I have sketched on this piece of paper.

Q. In making your discharge measurements?

A. The meter at the .3 depth in making the discharge measurement depended on the heavy weight, the 136 pound weight which was used on the meters.

Q. Then in making the discharge measurements you did not use this guy wire?

A. No, not in making the discharge measurements. The sag down-stream was very little for .3 depths. You understand the only sag of any importance was in, say spans 3 and 4. When I say any importance, I am referring now to

the discharge observations. The use of these big heavy weights prevented that possible down-stream sag of the meter, and the use of quarter inch cable, as light cable as we could possibly use under the circumstances.

Q. How much less do you think that sag was than in the case computed by Mr. Stewart when he made his measurements there for the Board of Engineers on Deep Waterways?

A. You mean for vertical curves?

Q. No, for horizontal?

A. You mean for discharge measurements?

Q. Stewart made a computation of the position of the meter on the chart and so on?

A. Mr. Stewart in certain of his observations also pulled the meter up-stream, but did not in all cases, I presume, get it under the Bridge chord.

Q. What different method or apparatus did you use from that used by Mr. Stewart?

A. Mr. Stewart used what are known as the sleeve weights on the cable, and used a heavier cable as I recollect it, in his observations with the 4a meter, and the sag downstream indicated without any pulling up to offset that was quite a bit, probably twice as great or more.

Q. How much greater?

A. Perhaps I better refer to a chart. I refer to a blueprint which accompanied a certain letter sent by me to Mr. Haskell in 1899, in which I presented the scheme of using the heavy weights and illustrated the desirability of doing this by this plan. The distance downstream below the bridge chord indicated by this plan, when the weight is not pulled up-stream, would be 12½ feet in 50 feet of water, with a surface velocity of 6½ feet. And the same sag down-stream indicated for the 12a meter, with the lighter weight, with the sleeve weights used by Mr. Stewart, was 32 feet.

Q. That is at greater depth or same depth? You mean 32 feet?

A. Yes, this is shown for the same station.

Q. What station was that?

A. It is one of the stations—

Q. Of mid-stream?

A. Of span 3, which is the deepest water we have to contend with.

Q. How deep was the meter?

A. Approximately 50 feet, 49 perhaps.

Q. That is it was 32 feet down-stream from the gaging section, is that right?

A. 32 feet down-stream from the plane of that lower bridge chord, yes.

Q. That is your gaging section, isn't it?

A. Substantially, yes.

Q. You let out a line which you—

A. The section really differs very little. I sounded it in three sections, one below the bridge chord, perhaps 10 feet; another one under the bridge chord and another one substantially under the upper bridge chord, and the acceleration indicated normally, as I recollect it, is not considerable.

Q. Then your former statement that the meter was at all times on the line of the section, at all depths, was not entirely accurate, was it?

A. I think you misunderstand the statement I have made to you. The chart here does not indicate the situation where the 80 pound weight has been hauled up-stream. It indicates the position where it is hanging verticallv. There is a chance to pull it up-stream about 16 feet here.

Q. How do you get different results from my statement?

A. My results in coefficients; when you say that in all other elements—

Q. I mean as to the sag or drift?

A. The main thing is in the use of lighter cable, quarter inch cable which reduced the current pressure, and also the placing of the weight in such a position that it was in the lowest velocities for the meter, and it was also vessel shaped, compact. We did not catch the current pressure as the heavy weights used by Mr. Stewart did.

Q. How much would the cable reduce it?

A. From 80 to 54 pounds, as I recollect it, after reading a letter recently concerning the matter.

Q. How much would the cable reduce the drift?

A. I would not be able to say that.

Q. Your conclusion as to the drift was the result of experiment?

A. Yes, it is the result of the measurement of the pressure of the current at different velocities on the meters concerned with the light cables concerned. And I had in mind also the form of the vertical curve, that is the variation of velocities from top to bottom.

Q. Is it your opinion that a cable ½ inch in diameter would assume a different angle or curve hanging in the water from a similar cable a quarter inch in diameter?

A. You mean the form of the curve?

Q. Yes?

A. Provided the same relations were maintained?

Q. Same velocity of current?

A. In the weight, same section, same velocity of current?

Q. Same point.

A. Same resistance on the weight at the bottom?

Q. Leaving the weight at the bottom out, just the cable, considering it was a flexible cable?

A. I don't know that I entirely get your question. Let us assume that as the cable enters the water surface the angle is ten degrees measured in a straight line between the snatch block and the water surface. That is the maximum of the cable.

If I understand your question, it is if under the circumstances in this particular case here we had two cables and the angle at the surface is indicated say as ten or twelve degrees, and the relation between the weight and the cable is similar, they would be substantially—

Q. Leaving the weight out, leaving no weight except the cable?

A. I can't leave the weight out because the curve is dependent on the weight as well as the other elements. That is we have this condition: With a cable which sustains a weight, and the meter may be a portion of the weight, the trend of the cable under those circumstances would be substantially plumb at the meter and the angle above the water surface is read, and if it were 12 degrees, the two cables would substantially follow the same curvature. So far as length is concerned, it would be almost exact.

Q. Is it your opinion that in these two cases the angle above the water would be the same?

A. That is an observed quantity.

Q. I want to know whether it would be?

A. If you are using sleeve weights, for instance, you have one condition. If you are using a weight down in the slack water towards the bottom, you have another condition. If you will detail definitely all your conditions, I will be very glad to do all I can to answer the question, but I cannot intelligently answer it otherwise.

Q. Will you indicate to us the effect of the different elements introduced by you which created a different condition from that indicated by Mr. Stewart?

A. In the case of the apparatus used by Mr. Stewart, the

sleeve weights are a certain distance above the meter, clamped on the cable. These sleeve weights were 20 pounds each, and were cylinders of cast iron. They covered a length of nearly ten feet of the cable, and the bottom-most sleeve weight, as indicated on this drawing, is about 12 feet above the bottom of the river, so that these cylinders received a considerable current pressure, the velocity being higher there than it is at the bottom; and the form not being a vessel shape enters in. I have already stated that the difference in current pressure on the cable as between the 3/8ths cable, as we call it, and the quarter inch cable, is from 80 to 54 pounds, a considerable betterment due to that.

Q. You mean that was the change of the force?

A. If you put a bigger cable crosswise of the current, the pressure on it of course will be greater.

Q. Is this difference in weight of cable or force of current on the cable?

A. It is force of current on the cable.

Q. How far down-stream from the guard rail is the end of the pier at the water surface?

A. It differs in the different piers. I do not know that I could make any statement concerning that. The pier between spans 2 and 3, of course is the pier on which the draw bridge is located, and is the length of the two spans, or a little longer. The other piers are placed on caissons below the water surface. I should say they extended—

Q. At the water surface?

A. I should say the caisson extends 10 feet below the—

Q. Does the caisson come to the water surface?

A. In some cases it is a little above the water surface.

Q. In which cases?

A. I do not know that I can explain this. Those piers, particularly towards the Canadian shore, the caisson shows a little above the surface as I recollect it. The piers I refer to are those between spans 6 and 7 and 8 and 9. The caisson there comes above the water surface. In other cases I believe it is below, except on the pivot pier. I am not sure about the pier between spans 1 and 2?

Q. How far is the pier, lower edge of the pier, from the guard rail, that is referring to the pier at the water surface in the spans where you say the greatest amount of water was flowing?

A. I should say six to ten feet. There was sufficient clearance on the piers, outside of the truss work for a man to very

comfortably operate the transit. I recollect it that way, in particular. We made observations by transit from the down-stream coping of the bridge piers. And in the case where the caissons came in, it extended a little further down still.

Q. Do you know what the total length of the pier was?

A. No. Of course on the up-stream side, the breakwater runs pretty well up, possibly 12 feet above the bridge chord, or more; I should say more than that.

Q. I refer to a paper dated December 20, 1899, by Clinton B. Stewart, M. W. S. E. page 450, of the Journal of the Western Society of Civil Engineers entitled "Discharge measurement of Niagara River at Buffalo, New York," the following quotation:

"The bridge is a single track railroad bridge having a plank walk about four feet wide on each side of the track. This afforded a favorable opportunity for crossing the river quickly in discharge measurements, and ease in reaching any station for work on vertical or transverse curves. The bridge consists of nine spans, which were numbered from the American shore, and having the following water widths and pier widths.

Span number.	Water width Feet.	Width of Pier
1	151.5	19
2	154.1	35
3	156.2	13
4	234.2	13
5	235.8	13
6	235.3	13
7	186.9	9.5
8	184.3	10
9	138.3	17
	1676.6	129.5

Total width of river equals 1806 feet. The piers have a batter on the sides of about one in twenty-four, so that the width of the intermediate spans may be taken as constant. They have a length of about 35 feet with a cut-water on the up-stream end, the down-stream end being rectangular in form." Do you have any reason to disagree with the statements of Mr. Stewart just read?

A. You mean as to the 35 foot—

Q. Any of those statements?

A. No, I have no reason to disagree.

Q. In a drawing attached to this paper of Mr. Stewart's the width of the bridge outside the guard rail is given as 18.5 feet. Do you question that?

A. No, I presume Mr. Stewart is accurate in his statement. I would like to add a little something to that quotation from Mr. Stewart, on page 451 of his report.

Q. All right.

A. After speaking of the piers, the downstream end being rectangular in form, he goes on again: "Eddies are produced by the piers to some extent, but they do not extend more than about 5 feet from the pier, and in most cases the current remains practically linear and with about the same amount of fluctuations as near the middle of the span. It is thought that little error has been introduced from this sort."

Q. How do you determine whether the water is eddying and so forth at that point?

A. The surface indications, and if it comes from a submerged indication, why it will show a little further downstream, as in the case of the caisson in span 6.

Q. That is pretty clear water through there?

A. You can't see bottom in any great depth; perhaps at certain times eight or ten foot depth.

Q. If the water was muddy, if there were any disturbance, the indications would appear at the surface?

A. The water is very seldom muddy, it is a clear—

Q. If it were muddy?

A. Not always transparent, but the translucent water of Lake Erie.

Q. Did you ever see the railroad bridge over the Missouri River at Omaha, when the river is muddy?

A. No, I don't think so. I do not know.

Q. You never observed the eddying appearance of the Missouri River at this point around the bridge span?

A. No, I am not well acquainted with the Missouri River.

Q. You never observed the eddies around the bridge piers at that point on the Missouri River where there was a great whirlpool, the water was apparently going around and around, did you Mr. Shenehon?

A. No, I have never observed that.

Q. How far would station 4 and two-twelfths be from the pier?

A. About 37 feet.

Q. On page 5343 report of Chief of Engineers for 1900, you said in substance that on the Niagara River, the surface

indication of direction was taken as the direction at all depths, is that correct?

A. Yes, that is true. I may make one reservation that preliminary to establishing the Open Section, a series of floats were sent down the river and the direction of the current plotted.

Q. I call your attention to two photographic copies of records of the United States Lake Survey Office showing the observed direction of the current at various depths at the Bridge Section, and ask you how closely those observations agree with the above assumption? I ask that these be marked Exhibits Shenehon's C and D, cross-examination. I will ask you also to state in that connection what they show as to the disturbance being confined to within five feet of the pier.

(Photographic copies referred to were here marked Shenehon's Exhibits C and D, respectively, Cross Examination.)

A. These observations, I believe, were those made with the four A, or direction current meter, and made under the direction of Mr. Stewart in his investigations, evidently in 1897.

Q. Were those made by Mr. Stewart?

A. Whether these are the angles which the current makes with the bridge, or whether they are deviations from the North or from the magnetic North, I do not know. The indications of the A mèter depend upon a magnetic needle and a repeating device in the instrument itself. That is likely to give some deviation from the true direction.

These were made in 1897, and the date shows that they were compiled by Mr. Harry H. Atwell, who was one of my assistants, February 21, 1899.

Q. They show variations in the direction of the current, do they not?

A. The observations show variations, and we can charge a portion of that up to the magnetic needle, I suppose, and a portion to the instrument itself; and some portion to the current.

Q. Did you make similar observations?

A. I made surface observations, and not with the meter.

Q. Not with the direction meter?

A. No. The measurements I made were made by suspending a float weighted down with chains from the upper part of the bridge and reading the angle indicated by the line which held it from floating down-stream.

Now, I would like to read from Mr. Stewart's report con-

cerning this, and I presume he is referring to these very sheets, or the data which these sheets contain. He says:

"Observations for the mean direction of flow of the river (page 463 of the report made by him, already referred to). In order to determine the mean direction of flow of the river, three discharge measurements were selected, in which the direction of the current for each of the meter stations had been observed and where the direction part of the meter had worked very satisfactorily." I interpolate that this indicates that there were times when it did not. (Continuing reading:) "This gave four sets of 21 readings each, and at distances apart of about 80 feet. The maximum range in direction of the current in any one of the sets was about 21 degrees.

The mean of the three sets gave an azimuth of 187 degrees from the magnetic south as the mean direction of the flow of the current. The variation of the mean direction at any point from the mean direction of the whole river would not exceed two or three degrees."

This appears, therefore to be a matter that does not have any large bearing on the volume of flow in this case.

Q. Did he say anything about individual variations?

A. No, the individual variations appear to be much as you would expect magnetic variations of that kind to be.

Q. What do these variations indicate? They indicate a disturbance in the water or eddying, don't they?

A. I think if you will watch a magnetic needle on a bridge, you will note that there are some disturbances that are not due to any current because it may not be immersed in the current.

Q. This gage was not on the bridge, was it?

A. Not at the time of observing in the current, but I am speaking now of an instrument that has some little movement as a current meter does, with the wheel turning and a magnetic needle incased in the same instrument. There are little fluctuations, you understand when it is entirely at the standstill. If you put a magnetic needle on a transit tripod and stand it up on a firm base, it will assume the magnetic north, but you would not expect an individual case—

Q. Does the repeater fluctuate?

A. The repeater?

Q. Yes?

A. The repeater is an instrument that simply goes on stopping for certain intervals until it is stopped by the magnetic needle itself, so the magnetic needle is the thing which determines what the repeater does. By many repetitions of

this form of observation, you doubtless get very good results, and I presume Mr. Stewart's statement of two to three degrees is a fair statement.

Q. Referring to station 4 and 6/12ths, I note that the surface is 190 degrees, and various points down show 280, 260, 250, 240, 245 degrees?

A. That is in span 6?

Q. Span 4 6/12ths.

A. Well, knowing the river there and knowing that is a mid-stream span of considerable depth and evenness of bottom and linear flow, I trust the river rather than the indications given by the instrument there.

Q. That is the largest discharge there, isn't it, the largest amount of water flowing through that particular span?

A. There is a little over 12 per cent. of the water flowing through that station 4 6/12ths. That is 12.23 of the volume of flow.

Q. Then you would not rely on the current meter indication on the direction?

A. I think a great many observations would doubtless give a value that would be so close to the truth that it would be sufficient as a mean, as Mr. Stewart has probably used it.

I wish to add in this matter of direction that any error which we have introduced into this work by reason of the putting in of too little direction correction means that we have made our discharge too great, which has a tendency to offset any error coming from the effect of turbulence making the discharge too small.

Q. Then if you have not considered the turbulence which is exhibited by these meter observations, you have failed to consider an important element?

A. But I have, and already testified to it. And I have shown how taking a very considerable portion of the cross sectional area, as I did, 20 per cent. of the depth in the open section, and assuming that the perturbation there was that of violent boilers referred to by Mr. Groat, and assuming that the current meter under registered 3½ per cent. through that area, the final effect of that would be if it did exist, which in my judgment it does not, would not be over ½ of 1 per cent.

Q. That is that there is no turbulence there?

A. No turbulence that would be denominated violent boilers, in my judgment, for any such depth as 20 per cent. of the depth.

I made an analysis of that also, Mr. Adcock, and it has

been referred to in this case in my 1900 report, so that has been very fully considered, and we have very definite information concerning it. I refer to the discussion of this matter on page 5332 of the report of the Chief of Engineers of the U. S. Army, for 1900, which is my report on the Niagara River. So we have given this the fullest consideration.

Q. Mr. Shenehon, in your direct examination, you referred to two observations by Mr. Sabin on ice effect in the St. Clair River, in the years 1900, 1901 and 1902. Will you point out to us what observations of ice effect Mr. Sabin made in either 1900 or 1902?

A. If you will refer to my testimony, you will see that my statement was, "Observations and Deductions."

Q. That is as to slope conditions?

A. If you will refer to my direct testimony, you will see that I did not speak of it as observations, but observations and deductions.

Q. Deductions?

A. Yes.

Q. What observations, I am asking about; I did not ask you as to deductions?

A. I beg your pardon?

Q. I did not ask you as to deductions. I asked as to observations. He made no discharge observations, did he?

A. During the ice conditions?

Q. In those years?

A. Yes.

Q. 1900 and 1902?

A. My answer was as to whether he made any discharge observations, the particular years?

Q. In those years?

A. He made observations of the slope of the river in those years, and from that deduced the effect of the ice. When I say he made deductions from the slope, I mean deductions, as I understand it, obtained from his prior discharge observations and the conditions that accompanied them.

Q. How long was the section over which the slope was measured?

A. I shall have to look up that matter. This is not entirely fresh in my mind as to just how he obtained the data.

Recess to 2:00 P. M.

After Recess, 2:00 o'clock P. M.

FRANCIS C. SHENEHON, resumed the stand and testified further on cross-examination as follows:

Mr. Adcock (Question read as follows): "How long was the section over which the slope was measured?

A. 4.4 miles from G. T. R. gage, to Dry Dock.

Q. Which would you expect to give more accurate results, the longer reach or the shorter reach? There was one from G. T. R. to M. B. R., two miles, wasn't it Mr. Shenehon?

A. Yes, the equation numbered two on page 2833, of the report of the Chief of Engineers for 1902, gives an equation depending on the fall from G. T. R. to Dry Dock, and equation number 3, on page 2824, is the fall from G. T. R. to M. B. R.

Q. Which would you expect to give more accurate results, the equation on the longer reach or the one on the shorter reach?

A. I have not sufficiently analyzed the situation to pass on it definitely.

Q. As an engineer, which would you choose, the longer reach or the shorter reach to determine the better results?

A. My answer to that would be that I should accept the conclusion Mr. Sabin reached in that matter after full analysis and intimate knowledge of the conditions involved, and so have accepted it in my testimony in this case.

Q. Whatever conclusion he came to you would accept?

A. Yes, on this matter of ice. That is the best conclusion I know of.

Q. That is the best information that you have?

A. That is my judgment, yes.

Q. So in the absence of any other information you would accept his statement?

A. I do not have any knowledge of any better determination, and when I say that, I have in mind the personality of Mr. Sabin, his ability and good judgment as an observer.

Q. How closely could you determine the discharge of the Niagara from the slope of the Buffalo gage to the International Bridge?

A. I could not answer that question without some investigation, or the plotting of the observations to see how they work out.

Q. Well, I suppose you have made calculations of this kind, haven't you?

A. In this particular position, the change of .1 at the Inter-

national Bridge, as I recollect it, has an influence about 2/3rds of 1 per cent. on the volume of flow, the backwater effect.

Q. I am speaking of the situation where you are simply taking your slope?

A. Yes.

Q. If you were asked to determine the Niagara from the slope between the Buffalo gage and the International Bridge, how closely do you think you could determine the discharge from such observations?

A. Well, I would have to know where the disturbance came from. That is if it were a backwater effect from the lower river it would be one thing, and if it is a change in the outflow conditions, that is the slope changing during unimpeded open flow conditions, then it would be another thing.

Q. Assuming it was a backwater effect?

A. With a sufficient number of observations, or considering a sufficient number of observations, I should say within 5 per cent.; just as likely to be on one side as another.

Q. Did you ever attempt to determine the flow of the Niagara River in that way?

A. Yes. The effect of the backwater on the Niagara River has been determined.

Q. Did you ever attempt to determine the discharge of the Niagara River from the slope relations?

A. No, I think not. I simply know within reasonable bounds the effect of backwater.

Q. What precautions were taken to prevent ice accumulating on the meters?

A. On the current meters?

Q. Yes, in the St. Clair River, by Mr. Sabin?

A. I should say that the ice does not accumulate on the current meter as a matter of fact. If you have a piece of ice on your current meter, and you immerse it in the water, the ice immediately disappears; the temperature of the water is such as to immediately thaw any film of ice that may be on the meter.

Q. Does it thaw the ice that is floating in the river?

A. I assume that Mr. Sabin was watching out for that very carefully, because he would lose his whole instrument if he allowed ice to accumulate on his meter. It would not only be a matter of interfering with the accuracy of the measurement, it would be a matter of stripping the meter from the cable.

Q. You don't know then exactly what precautions were taken?

A. No.

Q. The temperature in which Mr. Sabin was working was below freezing, was it not?

A. During the winter season, doubtless, but the water itself, the temperature of the water was above 32 degrees.

Q. And the meter would be colder than the water?

A. Yes. We had that condition at the International Bridge during the winter observations, the meter wheel in taking it out of the water would stop and be stiff. The minute you put it in the water again, the wheel falls out. When I say "the minutes," in a few seconds, the temperature of the water is immediately conveyed throughout the whole meter.

Q. Were there any other measurements made on the St. Clair River under ice conditions?

A. Measurements were made in 1898, two measurements. And measurements were made, eleven measurements in 1901, between January 2nd and February 2nd; and in February and March, 38 measurements; and then from March 25 to April 26, sixteen measurements. This was in the year 1901.

Q. Were those measurements for discharge?

A. Yes, those were measurements for discharge.

Q. How were they made?

A. By the ordinary methods. Those of 1898 were made at the Dry Dock Section, and the first 11 in 1901, at the Dry Dock Station, and then later Section Craig, was established, which I believe was a little further up-stream. The detail of these measurements is given on page 2835——

Q. Those are the same measurements you have been speaking of, aren't they?

A. On the St. Clair River, yes.

Q. Was 1901 an abnormal ice year?

A. Yes.

Q. Ice conditions?

A. Yes, it was one of the worst years we have any record of.

Q. So great that you rejected the discharge measurements on the St. Clair River in getting your increment, as appears on U. S. Exhibit 1?

A. Yes, U. S. Exhibit 1, shows the 1901 observations without correction for Lake St. Clair effect.

Q. If in February, 1901, the discharge of the St. Clair River was reduced to the extent of 85,900 cubic feet per second as indicated by Sabin's measurements, what became of the water that did not flow through the river?

A. It was doubtless impounded.

Q. In Lake Michigan?

A. Michigan-Huron.

Q. How much would that amount of water raise Michigan and Huron?

A. In the table number 7, the impounding value indicated for the year 1901, is .06 of a foot for January; February .18; March .11; April .14; and May .02, an aggregate of .52 feet or 6¼ inches. That answers your question I think, doesn't it?

Q. No. (Question read as follows: "How much would that amount of water raise Michigan and Huron"?) That is the amount of 85,000 cubic feet per second?

A. .18 of a foot would be the amount, the value. You understand when the lake goes up a little it also has an outflow value that compensates that in part.

Q. That was taken care of by Mr. Sabin in his reduced discharge, wasn't it?

A. I am not sure of that. Yes, that appears to be the difference between the discharge given by an equation and the winter condition derived by differences in slope.

Q. How much would a reduction of the supply to Erie by 85,900 cubic feet per second for 28 days lower the level of that lake?

A. The amount of value or the negative amount of flow would be .18 of a foot as indicated by this table of Mr. Sabin's.

Q. How much of that lowering would be compensated by reduced outflow at Niagara?

A. That question is a little complex. I think I can come somewhere near it: On the face of it it would appear to be about 9,000 cubic second feet.

Q. What change of level?

A. That would correspond to a half of the .81, or .4.

Q. What is that?

A. That corresponds to the difference in flow between an elevation, .8 or .81 lower or higher, half of that; half the difference of elevation.

Q. How much would it lower the lake? It would not lower the lake 4/10ths of a foot?

A. The effect would be just the converse of lowering of the lake; where the lake began to lower, of course it would shut off a certain amount of flow and that would be a quantity of a sign opposite to that of the sign of the lowering.

Q. It would be about .085 of a foot, wouldn't it?

A. You mean that amount of flow?

Q. Yes?

A. That is one month?

Q. According to your equations?
A. Yes, about an inch.
Q. About an inch?
A. Yes.
Q. Then other things being equal, Lake Erie should have lowered about .725 feet, is that right, during February 1901?
A. You mean that its elevation would be different than it would otherwise have been in the absence of this hold up?
Q. Yes?
A. That appears to be a fair deduction from the—
Q. Referring to the report of the International Waterways Commission on the regulation of Lake Erie, page 139, table 26, second column, what was the elevation of Lake Erie on February 1st, 1901?
A. (Referring to Table indicated.) On February 1st the elevation was 571.18; and March 1st, it is 570.94.
Q. How much had it fallen during the month of February?
A. The absolute fall appears to be about .24 of a foot.
Q. How much more should it have fallen according to the previous computation, .485 feet?
A. It depends on the local supply and run-off. That we cannot get out of this computation. We would have to go into the—
Q. At that point we launch into the realm of speculation, don't we?
A. At that point we launch into the realm of rainfall, run-off, melting of the snow and the other elements of that kind.
Q. How much does the local supply usually vary in the month of February?
A. I have no determination of that, but I should say for a particular year it would be a very difficult thing to state it; depending on the conditions towards the end of February; might have a very sudden fall that would give a large run-off one year and might—another thing, we have at that time the accumulation of the winter snows, and we are approaching the time of the breaking up.
Q. Suppose Mr. Shenehon, that during the month of February, as a matter of fact, in that time there were no rains to amount to anything, no thaws to amount to anything in the drainage basin of Lake Erie, what would be your answer then?
A. Well, I should not accept your assumption.
Q. I am asking you to assume that?
Mr. Hopkins: I object to a question based on a hypothesis impossible in fact.

Mr. Adcock: Q. Have you an answer now to that question?

A. What is the question?

Q. Assuming that there were no rains to amount to anything, and that there were no thaws of any considerable amount during that month on the drainage basin of Lake Erie?

A. You mean that the year was entirely normal?

Q. No, the month?

A. The month?

Q. Yes?

A. In that particular?

Q. Yes?

A. I can answer that question now: During the month of February Lake Erie normally rises 2⅝ inches, that is an average. Instead of that, in this particular year it went down as already testified to—

Q. About 3 inches?

A. Yes, three inches, so it appears to be abnormal to the extent of 5½ inches, around there; that is it appears to be lower where the indications from the volume which we have assumed would be 9½ inches. In other words our assumption of a normal year, of course may not be true, and we have that variation.

Q. How much rain would it take to raise Lake Erie five inches?

A. You mean on the lake surface itself?

Q. I assumed you could answer that question. On the drainage basin?

A. This is the month of February?

Q. Yes?

A. I should not expect a great deal of rain at that particular time. You mean precipitation, in whatever form it may be?

Q. Yes?

A. In what length of time, in one month? Let me get the question clear. What is the particular depth you are speaking of that I am to convert into rainfall?

Q. Five and a half inches?

A. A depth of 5½ inches over the whole drainage basin including the land and the Lake area for a month would amount to a flow of 5,500; that is assuming it all reached the lake, and is concentrated on the lake surface, 5,500.

Q. The question was how much rain would it take to account for that rise of the lake, 5½ inches? I understand from

your testimony the lake was 5½ inches higher than it would have been if this had been a normal year and Mr. Sabin's ice data had been corrected.

A. Let me make that clear: I referred to a mean annual curve of the movements of Lake Erie from month to month, derived from a large number of years. And I find that normally the rise of Lake Erie during that time was 2⅗ inches, during that particular month of February; and this particular year, with the abnormal ice condition, the lake went down three inches, it is a little less than three inches, so I made the aggregate 5½ inches.

Now, this would appear to me in excellent accord with the ice value as given by Mr. Sabin, because we cannot assume that for the particular month of a particular year that the run-off, precipitation, and the other factors are normal. We can take a long period of years and we can reach a fairly accurate conclusion, but when it comes to a particular month, I think we are all agreed that you cannot assume it a normal month. I think this is corroborative of the conclusions reached by Mr. Sabin. I see nothing to set aside the conclusion reached by Mr. Sabin.

Q. On the assumption that this was a normal year, then the effect of ice appears to have been less than 1/3 that deduced from Mr. Sabin's measurements, doesn't it?

A. No, the effect of ice would be about 60 per cent. of the actual computed value here; assuming the normal year would indicate that the ice effect was 60 per cent. of that indicated by Mr. Sabin.

Q. Do you know whether Mr. Sabin made any investigation to determine whether that was a normal year or not?

A. I do not. We haven't any basis for reaching a conclusion on that point for a single month.

Q. Of course his figures were made in 1901, in February and different months, weren't they, of that year?

A. I know of no expert in meteorology or run-off or rainfall, who can tell what happened in 1901 as to run-off.

Q. That is at the present time?

A. I do not think it is determinable.

Q. Wouldn't it have been possible—

A. It is not determinable from any measurements that we have.

Q. Wouldn't it have been possible to obtain observations as to that?

A. You mean of each stream in the run-off basin?

Q. Yes? That is for the month of February, and also the precipitation, take account of that on the lake surface?

A. I think we are reaching the realms of speculation, now.

Q. You could at least determine whether it was an abnormal year.

A. I believe this is an excellent check on the conclusion as to ice—

Q. I know what your belief is?

A. I am trying to give you the reason on which this belief is founded. You are endeavoring to discredit Mr. Sabin's work by assuming he can tell what the run-off is for a particular month, which I do not agree with.

Q. Wouldn't it have been possible to have determined whether or not the conditions were abnormal in February, 1901?

A. You mean as to the run-off?

Q. As to the run-off, as to whether it was abnormal so as to raise the lake 5¼ inches. That would be an abnormal thing, an abnormal condition.

A. The lake did go down about three inches, at a time when normally it would go up 2⅝ inches.

Q. But in order that Mr. Sabin's work, figures, may be correct, there must have been that year an abnormal condition as to run-off or precipitation on the lake surface or the drainage area?

A. So far as any individual month or any individual year is concerned, we may regard it as abnormal. In other words it will not fit the mean. The chances are every year is an abnormal year, every month is an abnormal month. The actual amount of lowering of Erie checks the computed from Sabin's ice effect, 60 per cent. of it.

Q. As a matter of fact there must have been an abnormal condition that month, wasn't there, in order that Mr. Sabin's conclusions with reference to the ice conditions on the St. Clair River should be correct?

A. I have stated that in matters of the particular value of the run-off and the precipitation for a particular month, that we would not expect any month to fit a mean curve; and therefore the presumption always is that it is abnormal.

Mr. Hopkins: You do not mean it is abnormal, but just that it does not fit the mean?

A. I mean it will not fit the mean value.

Mr. Adcock: Q. Then the conditions were such that they did not fit the mean. Is that right?

A. Yes, that is true.

Q. They did not fit mean conditions?

A. Yes.

Q. As an average of ten years, for how many months is the surface of the St. Clair River covered with ice, how many months of the year?

A. I should say not to exceed three months as an average, and possibly a little less than that. The months of January, February and March, or possibly a little bit earlier, starting in the latter part of December, around Christmas time. Of course that varies from year to year. Where we have ice jams, they may last through April, and do. In this particular year in 1901—

Q. This ice proposition is more or less indeterminate, isn't it. You haven't had any observers out?

A. Any particular year you are speaking of now?

Q. You have never had any observers out there from the Lake Survey looking at the ice, have you, whose duty it was to make a report?

A. Sabin—

Q. Sabin made a report?

A. His report on ice is printed, and that of course you are familiar with.

Q. Yes?

A. The ice condition is reported by the weather department at Washington and bulletins are issued relating to ice conditions, but that has more to do with the opening of navigation, so that they may anticipate the date on which vessels may sail.

Q. But you people in the Lake Survey did not make any observation with reference to that except as Mr. Sabin did in 1901, that abnormal year?

A. You will remember on the St. Lawrence River I made certain deductions as to ice effect.

Q. I am speaking of the St. Clair.

A. You will remember on the Niagara I have certain conclusions and observations. But on the St. Clair, I think that we have mentioned here is the Lake Survey data as to ice conditions.

Q. There seem to be a lot of conclusions with reference to ice and so on, without very much actual basis as to observations made?

A. I have an impression from the testimony beginning with Mr. Freeman's—or beginning earlier with the testimony of the Government witnesses, and then including the very fine discourse by Mr. John R. Freeman, on ice conditions, par-

ticularly in the St. Clair and St. Lawrence Rivers,—then I had in mind the testimony of Mr. Kent on that point, and it appears to me that we know very definitely, and that we can pick out in the profile shown by Mr. Freeman the years when these ice effects are very pronounced.

While I am touching on this, I wish to reiterate a thing I have stated before that when Mr. Williams made his physical analysis of the lakes, through inadvertance I presume, he picked this particular series of years in which this large ice effect appears, and from which we may make deductions as to ice effects of other years, and then regarded is as annulled or balanced by ice effect in the other rivers, whichever way you wish to consider it.

Q. But there was no one in the Lake Survey whose duty it was each year—

A. No.

Q. Each month of the winter season to make observations as to ice?

A. That is true. I have in mind another case, however, where Mr. Graves was detailed to run some levels, read some gages, so as to determine the slope of the river, at the time of another ice jam; but I do not recall the year. But there has been, so far as I am aware, no regular observation year after year, winter after winter of the ice conditions of the St. Clair River, except as the weather gages may give some information on that point.

Q. What is the average thickness of the ice?

A. I could not tell you. I have never investigated the ice on the St. Clair River, that is the ice itself.

Q. Leaving out the question of ice jams, by what percentage does this ice cover reduce the discharge of the St. Clair River?

A. I could not answer that question.

Q. You don't know how much of an influence this would have on the annual discharge, do you?

A. Basing that on the years that Mr. Sabin discussed and his conclusions—

Q. I am excluding ice jams. I am speaking of ice cover.

A. Oh no, I should not expect that to be a very big quantity; might be somewhere between five and ten thousand second feet during the time the ice cover was on.

Q. For how long a time during an average of ten years, do the ice jams last in the St. Clair River?

A. That I cannot inform you upon.

I wish to make one other statement here that will clear up this matter of 5½ inches. When I state—

Q. I thought you had covered that subject?

A. No, I have not. There is one thing I think should be put in to make it quite clear that there is one little thing that we have not fully considered in making this confirmation.

I said that the normal rise of Lake Erie during the month of February was 2⅝ inches. That normal condition includes the ice effect. There is every year an ice effect possibly of 3½ inches or something near that, would be a possible average measure. So in the end, where we have stated here that we show only 5½ inches, we are entitled to add something to that for the average mean normal ice effect, which shows in the curve. So really our correspondence with Sabin's figures is very much closer than I stated before. That fact did not occur to me when I was discussing the matter; but that is quite pertinent.

Q. By what percentage on an average do the ice jams reduce the discharge of the St. Clair River?

A. I think our information concerning those is mostly summed up, so far as the exact figures are concerned, in Sabin's tabulations. Of course we can draw some inferences, with some reservations, from the relative elevations of Lake St. Clair and Lake Huron; the effect reflected from the Detroit River upon Lake St. Clair, which would be in the nature of a lifting up of the lake when ice jams were in the Detroit River, and a lowering effect in Lake St. Clair when the jam was in the St. Clair River. Those two things may occur at the same time, so that we see no ice effect when retardation actually does exist.

Q. Sabin showed an average for the five months of about 55,000 cubic feet per second, did he not, which was about 25 per cent. in the abnormal year of 1900-1901?

A. Sabin for the three years in which he has set down values, the three winters, is perhaps a better way of stating that, shows for 1900 a loss which spread over the whole year, the whole twelve months of the year, would amount to 12,510 cubic second feet.

Q. That would be about what per cent. of the entire flow?

A. Thinking of the flow as 200,000, would be about 6¼ per cent.

Q. Then for 1901 he made it about 50,000?

A. 1901, if it is spread over the whole year, it would amount to a flow of 20,640, for the year 1902—

Q. How much is that what per cent. is that, about ten per cent.?

A. That is about ten per cent., a little over. For the year 1902, spread over 12 months, he makes it 9,470, and the mean of these three years indicates about 14,220. That would be a flow that spread over the whole year would amount to 14,220 about seven per cent. of the flow.

Q. Russell, however, after further study of these conditions in 1904, reduced Sabin's estimate to 27,000 cubic feet per second?

A. With certain definite reservations.

Q. Or less than six per cent. for the entire year, wasn't it, for the year 1901?

A. Mr. Russell made a discussion, as I recollect it, that is based on the relative elevations of Michigan and Huron, or Lake Huron and Lake St. Clair, and Mr. Russell himself speaks of the indetermination of the method of procedure, as I have done in a similar discussion on the St. Lawrence River.

Q. Now, that year 1901, was an abnormal year, wasn't it?

A. Sure.

Q. That is the ice effect in an average year, or running over a period of ten years would be a good deal less than that?

A. Yes, I get an average of 14,220, covering the whole year for these three years. I should say it is less than that, probably eight or ten thousand, in the average year.

Q. You do not think much of Russell?

A. Mr. Russell?

Q. Yes?

A. I have great respect for Mr. Russell.

Q. I thought you spoke of him, not in the commendatory way that you have spoken of some of the other men in the Lake Survey?

A. No, Russell is a different type; he is a computor. That is his main work in the office of the United States Lake Survey, and he is a most excellent computor, a very valuable man, but a man whose judgment we do not always trust.

Q. Mr. Hayford was a computor too, wasn't he?

A. Hayford is of a different type. I do not wish in the slightest to discredit the work of Mr. Russell. I think what you have in mind is my judgment as to his considering the run-off of the Lake Erie basin as 60 per cent. of the rainfall. That of course I regard as a very serious misstatement and misjudgment, and on that are based the other things that

have troubled Mr. Russell in adjusting the flows of the various rivers.

This 81.4 inches of evaporation, as I understand it, grows out of that erroneous conclusion or generalization as to the run-off of the Lake Erie basin.

Q. According to the best information that you have, what is the average run-off per square mile of the Great Lakes Drainage basin?

A. The conclusions reached by Mr. Williams in his investigation of the streams should rank as the best determination we have, and he shows during the months June to November inclusive, a mean value of roundly a quarter of a cubic foot per second per square mile of drainage basin.

Q. Where?

A. Lake Erie basin.

Q. I asked for the whole drainage basin of the Great Lakes.

A. The whole drainage basin?

Q. Yes? I asked for the run-off per square mile of the drainage basin of the Great Lakes?

A. You mean the average?

Q. For the year?

A. Well, that could be gotten by taking the volume of outflow of the St. Lawrence River and dividing it by the drainage basin.

Q. Suppose you do it and tell us what it is. Refer to Table LVIII of Williams' Exhibit 34 (handing witness same).

A. Let me ask you a question: Is this a question as to the run-off of the land?

Q. No, the entire drainage area?

A. Including the lake surfaces?

Q. The entire drainage area. That is what Mr. Russell based his figure on.

A. I have divided the volume of flow of the St. Lawrence, which I have taken as 240,000 cubic seconds feet, by 287,700, which is the drainage area of the Great Lakes including the lake surface itself, and find that the average yield per square mile is .83 of a cubic foot per second per square mile of area.

Q. What did Mr. Russell take?

A. Mr. Russell took for Lake Erie 30,300, as I recollect it.

Q. About the same amount, wasn't it?

A. A little less .74.

Q. That was for the entire drainage basin of Lake Erie, including the lake surface, wasn't it? Now, what do you consider the average run-off per year on the Lake Erie basin to be, the drainage area I mean?

A. For the year? I have no better figures than those given by Mr. Williams, and his figure is 0.66 for Lake Erie.

Q. Mr. Russell took .684, didn't he?

A. The computation I have just given you would indicate 0.774.

Q. Is that a serious error, do you think, so much so that you would condemn Mr. Russell for it?

A. Yes, when used through the months of June to November inclusive, because Mr. Williams' figures for that time are practically 1/3 of those for Mr. Russell. In other words if Mr. Williams is correct during that period, and the method by which he derives his values would indicate that, then Mr. Russell was 200 per cent. in error.

Now, understand, this is not the volume of flow from the land basin as Mr. Williams' value is, so you have compared Mr. Williams' run-off from the land area with the yield of the whole basin including the lake, as indicated by Mr. Russell.

Let me go a little further on that: 60 per cent. of the rainfall, as I figure it, would be about a foot and a half, a cubic foot and a half per second per square mile of area, so where Mr. Williams gets .66 cubic foot per second, Mr. Russell gets a foot and a half, so Mr. Russell there, if Mr. Williams is correct, is over 100 per cent. in error.

Q. Do you know the common figures for the run-off of watersheds and percentage of rainfall?

A. I know some of them. I don't carry things of that kind in my mind. I happen to have in mind the figures for Minnesota. We think of four inches for run-off for 26 inches of rainfall.

Q. Well now Mr. Russell is the computor of the Lake Survey, is he?

A. Yes, a very excellent computor.

Q. He makes computations with reference to observations that are made in the field, does he?

A. Yes, and he has in the past made observations. Mr. Russell has done some of the geodetic work of the Great Lakes. He at the present time goes out and makes magnetic observations for the variation of the compass, and he made some measurements of flow of the St. Mary's River.

Q. He is in a good deal the same work that Mr. Hayford who testified here is in, the Geodetic Survey Work, isn't he?

A. I think Hayford's position was quite different from Mr. Russell's. Hayford was Chief of the Computing Division,

with a great many assistants, and Inspector of Field parties as well. His was an executive, supervisory, large position.

Now that you speak of Mr. Hayford, I would like to make a correction in a statement I made in my testimony. You asked me as to whether or not I knew what Mr. Hayford was to testify about. I told you not in detail; that I knew that he had found the results to be precise. But in looking over some of my records, I find that on the morning preceding his evidence—he gave his evidence on the afternoon of the tenth—in the morning I spent a couple of hours with him and we went over his testimony, and I did set down at that time the actual maximum and probable errors that he had derived; that is in discussing with him the testimony which he was to give in the afternoon; it was on the same day. I had in mind that I took that down as he testified.

Q. Did the Coast and Geodetic Survey have anything to do with the measurement of discharge of streams, determination of increments?

A. I believe not. I think I ought to explain however that in bringing Mr. Hayford into this case, under my recommendation, I had in mind the man who was most capable in my judgment of any man I know of in the world—

Mr. Adcock: I move to strike that out. I have not asked him any question as to that.

The Witness: (Continuing)—to discuss physical observations, and there was no other purpose on my part. Any conclusion he might reach would go into the case after he once started.

Mr. Adcock: I move that be stricken out as not responsive to any question put to the witness.

The Witness: Hayford has an international reputation as an observer, and a man who reduces physical observations and discusses them.

Mr. Adcock: I move that be stricken out as not responsive to the question.

The Witness: The question was whether Mr. Russell and Mr. Hayford were about of the same type.

Mr. Adcock: No.

The Witness: That was my understanding of the question.

Mr. Adcock: I didn't ask you that question. I asked you as to whether or not the Coast and Geodetic Survey made any measurements of the discharge of rivers and determined increments of any streams?

The Witness: I answered that question, and answered further in response to your prior question.

Mr. Adcock: You know Mr. Shenehon, I am perfectly willing—my objection along this line is simply to lead you on because you show your interest by going outside of the questions that I ask you, and to volunteer. But I would like you to confine yourself to the questions which I ask.

Mr. Hopkins: I object to statement of counsel in commenting on what the witness' manner shows. It is no part of counsel's business to do that.

Mr. Adcock: It is a part of counsel's prerogative.

Mr. Hopkins: The witness might say, showing every effort to tell the truth also.

The Witness: In my answers Mr. Adcock, I am assuming that on both sides—perhaps I am assuming too much in that—we are endeavoring to get the real truth before the court.

Mr. Adcock: We are endeavoring to get the truth certainly, and in a lawsuit we have got to confine ourselves to questions and answers, the answers being—

The Witness: So as not to get the wrong side of the truth.

Mr. Adcock: (Continuing) The answers being responsive to questions.

Q. Now, will you answer the question with reference to the scope of the work of the Coast and Geodetic Survey?

A. I think the testimony will indicate that I have answered that already.

Q. They do not have anything to do with that?

A. No, not to my knowledge. They do however make hydrographic examinations, geodetic and magnetic observations, a great many physical observations that require reduction.

Q. As a computer in the Lake Survey, Mr. Russell has had considerable experience with computations with reference to observations to determine discharge of rivers, and relate such discharge to elevations of the lake, hasn't he?

A. Yes, he even reached a conclusion as to the lowering caused by this Chicago diversion, which was a little over six inches in Lake Michigan, as I recollect it.

Q. Will you tell us what is the weight per foot and the horizontal force of the current per foot used by you in computing the position of the meter in the Niagara River work on the International Bridge?

A. The question is as to the pressure?

Q. Yes?

A. On the current meter?

Q. Yes?

A. And the pressure on the cable per unit of length for different velocities and for different depths?

Q. Yes?

A. I do not carry those values around with me. They are matters of record in the office of the Lake Survey; and I have a curve up at my office in Minneapolis that shows the relationship between velocity of flow and the wire, cables, I believe also. But we made definite, careful observations of those things, and our estimation of the meter and its approximately correct position in the vertical, and up-stream and down-stream was worked out with the full knowledge obtained by these observational data.

Q. Where is that data?

A. In the Lake Survey office as I recollect it, and yet some of those observations, I believe, were made by Haskell for the Board of Engineers on Deep Waterways, and the data may be in the archives of the Government in some other place. But those were very carefully made, and I believe we secured correct results.

Q. Do you know what the position of the meter was in those various depths in your coefficient work, with reference to the guard rail?

A. You mean up-stream or down-stream?

Q. Yes?

A. Oh, I suppose we may have been in error three or four feet.

Q. You may have been down-stream three or four feet?

A. Yes, I think that would be a possibility.

Q. Might it have been further down than that?

A. As I think of it, that would be about the limit of it.

Q. It would be about the limit?

A. Yes.

Q. How far up-stream could you draw your cable?

A. I don't remember the exact limiting amount. I have it in mind as possibly ten feet. I think that would possibly mark the limit.

Q. In deriving an increment for the St. Clair River from the observations at the Dry Dock Section, is it in your judgment possible to ignore the position of Lake St. Clair and arrive at correct results?

A. Not to ignore Lake St. Clair, that is not the right word.

Q. Ignore the position of Lake St. Clair?

A. Speaking of an individual discharge or a short series,

we need to take into account Lake St. Clair; and in the end, an equation that does not contain Lake St. Clair as one of the elements, the backwater effect there, could not be applied to individual observations.

In the chart, U. S. Exhibit Number 1, in this case, Lake St. Clair was not ignored; it was specifically stated on the chart—specifically stated in the evidence that the period of time over which the observations extended was such that I felt safe in not entering that term in the question.

Q. What is your opinion now?

A. I think it is better to have an equation that does take into account Lake St. Clair.

Q. Do you think it would be proper to use one that did not?

A. It would depend on the purpose.

Q. For the purpose of deriving an increment?

A. Well, when you say the purpose in this case—

Q. I didn't say the purpose in this case. I said for the purpose of deriving an increment.

A. I so understood.

Q. For the St. Clair River?

A. I think it is preferable to use an equation as has been done in later equations in which the two terms appear.

Q. You think it would be proper for you, from an engineering standpoint, to derive, attempt to derive an increment without taking into consideration the position of Lake St. Clair?

A. Oh, yes, as indicated by U. S. Exhibit Number 1, I think that was entirely justified, with the explanations in my evidence of 1909.

Q. At that time, you did not take into consideration the position of Lake St. Clair?

A. Yes, I took it into consideration by assuming that the time over which the observations extended was such that we could—

Q. The Lake Survey later in deducing their equations have taken into consideration the position of Lake St. Clair, have they not?

A. Yes, it is a very proper thing to do, and it is especially pertinent and proper where the curve is to be used for a physical analysis. It would have been improper to use this particular curve here in a physical analysis, that is seeing whether or not we could take the volume of flow and in-

terpolate the local supply and come to another river. That was an improper use of these curves.

Q. Then if we should take all of the discharge measurements on the St. Clair at the Dry Dock Section and refer them to the corresponding elevations of Lake Huron, as reported in the Government reports, and should determine by any accurate method the inclination of the average line represented by the whole series of observations, do you consider that a reasonably accurate increment would be obtained?

A. Yes, I should think so. The analysis of the Lake Survey has tended to show that each season has a little difference in the volume of flow.

Q. Suppose we just try that. Assume that the center of gravity of the upper group at elevation 580.92, was 203,382?

A. How many observations and elevations?

Q. Whatever there is in that group?

Elevation 580.92, all of the observations that would fall into that group, 147. And the lower group, elevation 580.35, discharge 187,082, 150 in that group, what is the increment?

A. That would give an increment of 28,600. I notice however that you have given me 297 observations where the Lake Survey has gotten an increment with 488 observations.

Q. Would you say that there are more than 297 observations at the Dry Dock Section?

A. No. That would include the Gorge Section.

Q. Have the discharge observations made since 1903 on the St. Clair River shown any change in the flow of the river from the conditions of former measurements?

A. A variation from year to year has been indicated by the observations; not only those since 1903, but the whole series as reduced by the Lake Survey.

Q. The later ones have shown nothing really new then?

A. The changes have been, not progressive, but back and forth.

Q. When you prepared U. S. Exhibit number 1, you believed the increment thereon shown of 23,820 cubic feet per second to be correct, did you not?

A. No, I so stated in my testimony, that I believed it was subject to a possible error of 25 per cent., and my judgment was that the increment was somewhere between 18,000 and 24,000.

Q. Were there any observations included in the derivation of your increment for the St. Clair, that were not used by Mr. Wheeler in the derivation of the increment of 25,300

cubic feet per second testified to by him on direct examination?

A. The observations are plotted on U. S. Exhibit Number 1, and in my evidence I stated, as I recollect it, that the year 1901, and the year 1908, were not used in computing the increment. But the observations of 1901, as adjusted for the abnormal stage of Lake St. Clair, appear to be in reasonable accord with the other observations.

Q. You haven't answered the question yet, Mr. Shenehon?

A. What is the question?

Mr. Adcock: Will you read the question?

(Question read as follows: "Were there any observations included in the derivation of your increment for the St. Clair that were not used by Mr. Wheeler in the derivation of the increment of 25,300 cubic feet per second testified to by him on direct examination?"

A. My recollection is that Mr. Wheeler did not use anything after the year 1902.

Q. All of the measurements were available, weren't they?

A. Just one minute, let me think about this: I am thinking of Mr. Wheeler's report of 1903. It is my recollection that Mr. Wheeler used the same observations, that is excluding 1908. I think he did not use any observations in 1908.

Q. He did not use any of those?

A. Not in making the computation, but I presume Mr. Wheeler did include the year 1901, yet I am not positive; I would need to refresh my recollection by reading over Mr. Wheeler's testimony.

Q. He got an increment somewhat different from you, didn't he?

A. 25,300.

Q. You did not use any observations that Wheeler did not use?

A. I say I would need to read over again Mr. Wheeler's statement concerning that before I could give you an answer to the question. I would be very glad to take the time to do that, if you care to have me.

Q. I would like very much if you would do that, but not now. You can do it some other time, and send the Commissioner the answer to the question.

A. All right.

Q. If the observations of 1901, had been included by you without correction, the increment would have been about 27,800 cubic feet per second, would it not?

A. I can't tell you.

Q. What is your best judgment on that?

A. I would not have any judgment without—

Q. You would have to plot them would you?

A. Yes, I would need to look into the matter.

Q. The improvement planes for Lake Erie were originally 9.03 feet below Huron, were they not; that is prior to 1893 or 1894 or 1895, along there?

A. The improvement planes, there are somewhat different elevations.

Q. I am speaking of the relation; the improvement plane for Erie, Huron?

A. I am not certain the improvement planes are just the same for all contracts.

Q. Were not the relations changed along about 1895?

A. Yes, at the time the 20 and 21 foot project was gotten under way, it is my recollection that the improvement plane was made nearer the low water elevation instead of a mean.

Q. At the present time, the improvement plane for Erie is eight feet below the improvement plane for Huron, is it not?

A. I should have to look up those figures. I do not carry them with me.

Q. Prior to about 1895, the improvement plane of Erie was 9.03 feet below the improvement plane of Huron?

A. I don't recollect the elevations of the improvement planes.

Q. You have not considered that proposition?

A. As I recollect the thing, the intent was to get as deep a channel as possible, and not only were the 20 and 21 foot projects gotten under way, but a little additional gain over that was gotten by referring to lower water.

Q. Why should they change the relation of Erie to Huron?

A. I am unable to tell you why they did this thing or that thing.

Q. It would be interesting if that were the fact, would it not?

A. I do not know. I presume the reports from the officer on one lake might have indicated that he would prefer that the improvement plane for Lake Michigan-Huron be so and so, and the officer on Lake Erie might recommend another, and this would be adjusted in the office of the Chief of Engineers.

Q. In that "melting pot" there is the Chief of Engineers' Office?

A. I have not struck that melting pot.

Q. You desire to obtain, do you not a depth of water substantially the same all the way along, so that there would be no object in having the water a foot or two deeper in the channels or harbors of Erie, whatever they may be, than in Huron?

A. As an illustration, they are building the Soo locks for a draft of about 24 feet of water, and the channels of the lakes are 20 to 21. Some harbors are dredged deeper, and there may be particular places that are dredged deeper still.

Q. Take it over a long period of years, Mr. Shenehon, the mean stage of the lake, any particular lake, is substantially the same as the stage of the same lake for another similar period of years, is it not?

A. It depends on the number of years considered.

Q. Well, what number of years would you say?

A. If you should take a series of years around 1895, you would find fairly low water.

Q. No, I am speaking of a number of years. What number of years would you consider necessary to make a comparison, so that the stage of the lake would be substantially the same in the two periods?

A. It would depend on my object in the investigation. That is specifically the object which you wish to obtain. I may be able to—

Q. Take for instance Lake Superior, or Lake Michigan—Huron, assuming the channels connecting the lakes are unchanged, say for 10 or 15 years, whatever it may be, assuming you find the mean stage of Lake Michigan-Huron, say, at a certain elevation and then you compare the stage with another period of years, you will find they are approximately the same, will you not?

A. Not necessarily. I think that is illustrated in the exhibit put in this case known as "the red and the blue," in which we show five year periods, show changes in the elevations of the various lakes.

Q. Take ten years?

A. No, the ten year periods will not show exactly the same for the same lakes.

Q. How near?

A. I should not be able to state.

Q. Assuming that the channels were not enlarged or decreased?

A. For Lake Ontario for instance, one ten year period as compared with another may show a difference in elevation of nearly a foot.

Q. How long periods?

A. Those were ten year periods.

Q. How about 20 year periods; two 20 year periods?

A. There would be a difference of half a foot, possibly more. I would be very glad to take specific periods, if you—

Q. What was the elevation of Lake Superior from 1860 to 1889?

A. 1860 to 1889?

Q. Yes, inclusive?

A. I refer to table number L of Williams' Exhibit 34, which I assume has been correctly worked out. The elevation of Lake Superior for that period, 1860 to 1889, is 602.27.

Q. Now, these lake levels bear certain relations, do they not, to one another? I believe you stated that you could predict the level of Erie from Huron, did you not, in your direct examination?

A. In five-year periods you can come very close to a prediction of what Lake Erie would be from the elevation of Lake Huron.

Q. What was the elevation of Michigan-Huron for 1860 to 1889?

A. I refer to table XIX, of Williams' Exhibit 34, which I assume to be correctly worked out. The elevation stated there for Huron, 1860 to 1889, is 581.91.

Q. The difference is what?

A. 20.36 feet.

Q. What was the difference between the elevation of Huron and Michigan, from 1890 to 1910?

A. I refer to the continuation of Table XIX, Williams' Exhibit 34, the second sheet, which indicates the elevation of Huron 580.48, that is, for the full year.

Q. What was the elevation of Superior for this period?

A. The elevation indicated in Table L, of Williams' Exhibit 34, sheet, 2, is 602.36.

Q. That is substantially the same as from 1860 to 1889, is it not, for Superior?

A. Yes, a little bit higher.

Q. A very small amount?

A. About an inch, I should say.

Q. And Michigan-Huron was about a foot and a half lower, wasn't it?

A. The difference between the elevation of Superior and the elevation of Huron for these latter years, is 21.88, and this indicates for the latter period as compared with the former, 1.52 lower.

Q. A little over a foot and a half?

A. Yes.

Q. What was the elevation of Superior from 1890 to 1900?

A. Of course I should call attention to the fact that the building of the International Bridge raised the level of Lake Superior about six inches.

Q. Will you kindly answer my question?

A. The elevation of Superior, as handed me by Mr. Williams, for the years 1890 to 1900, is 602.28.

Q. And you are stating that as the correct figure, are you not, Mr. Shenehon?

A. Subject to correction.

Q. The only thing is, we do not want to have any question in the record as to figures that you give. What was the elevation of Michigan-Huron from 1890 to 1900?

A. 580.34, is the figure which Mr. Williams gives me, which I state now, subject to checking and possible correction.

Q. The elevation of Superior and the elevation of Michigan-Huron, from 1890 to 1900, compares substantially with the elevation for the 20-year period from 1890 to 1910, does it not?

A. Yes, within an inch.

Q. And the difference in elevation is 21.94?

A. Yes.

Q. Now, the elevation of Superior from 1901 to 1910, is 602.46, is it not?

A. I set down that figure as given me by Mr. Williams, with the reservations made to the earlier figures.

Q. And the elevation of Michigan-Huron is 580.65, is it not?

A. 580.65.

Q. 1901 to 1910, making a difference of 21.81?

A. 21.81, I have that.

Q. That shows that from 1901 to 1910, Michigan-Huron were higher in comparison with Superior than they were from 1890 to 1900, does it not?

A. Yes. I should make a reservation, however, by stating that under an arrangement made by the Federal Govern-

ment with the power companies at Sault Ste. Marie, they were not permitted to lower the level of the lake below a certain point. In other words, that is a period where it has been under regulation, so that the power companies are compelled to shut down and cease to—

Q. When did this take place?

A. That is sometime about 1900, maybe a little later. I am not certain of that date.

Q. About 1900. 1907, wasn't it?

A. I have in mind the building of the power canal there. That was under way prior to my leaving the Soo in 1898, and it has been opened since about 1900, but I should need to look at the date.

The two spans of the International Bridge nearest the Canadian side had regulating gates put into place, which, however, have never been operated as gates. They simply block the flow, the portion of the flow in those channels, but I have the impression that the date of the building of those was earlier than the year 1902, which Mr. Williams tells me was the date of the washout under the power house at the Soo.

I should need to look up the dates to speak with any sureness on that point.

Q. You mentioned 1902, or about that?

A. Yes.

Q. The withdrawal of water from Superior was regulated, that is, through the power canal, was that true?

A. Yes, the power companies operated under a limitation. If the lake got below a certain level, they were compelled to shut down until it returned to that level.

Q. You do not think that the regulation affected the mean elevation of the lake materially, do you? That is, Lake Superior.

A. Yes, if the power companies had not shut down the water would doubtless have gone to a lower point. In other words, it would have the same effect as a diversion through an independent canal. They would have gone on draining off Lake Superior by adding to the natural overflow, the flow through the power canal. That is true of the Canadian side as well, and yet whether or not the Canadian Government imposed any restriction there or not I am not certain.

Q. In the elevation of Michigan-Huron as compared with the elevation of Superior from 1901 to 1910, and from 1890, to 1900, there is not much difference, is there?

A. No, under those conditions, a period of low water in

Lake Superior, Lake Superior would be maintained at the expense of the lower lakes, of course.

Q. Well, that would have led to the lowering of Michigan-Huron, wouldn't it?

A. Yes.

Q. But from 1890 to 1900, the relation was the same as it was from 1901 to 1910, practically?

A. Well, let me see, that is from 1890 to 1900?

Q. Yes?

A. That was the period in which Lake Superior was impounded for the building of the International Bridge. Lake Superior was raised six inches, and the water was impounded at the expense of the lower lake at that time.

Q. How much was it raised?

A. About six inches.

Q. And Michigan-Huron fell a foot and a half?

A. Then of course the period, 1900 to 1910, we have the Chicago Drainage Canal.

Q. But you do not see any effect from the Chicago Drainage Canal here, do you on the relation of the levels of Superior to Michigan-Huron?

A. I think under those conditions the thing would be masked.

Q. The relation of Huron to Superior for the last ten years is the same as for the ten years between 1890 and 1900?

A. As I have stated, it is a matter of compulsion to hold it there. The Federal Government saw to it that the lake did not go below a certain point.

Q. How do you account for the change in 20 years, that Michigan-Huron is a foot and a half lower the last 20 years, that is from 1890 to 1910, than it was during the period prior to 1889?

A. I do not try to explain a difference of that kind in detail, and closely.

Q. That is a physical condition?

A. I have already stated to you we have two things coming in the elevation of Superior there. Between 1890 and 1910, we had the building of the International Bridge which raised Lake Superior, as I have stated, about six inches, and during the same period we had the regulation of the power companies, which did not permit Lake Superior to go below a certain point.

Q. How much did the building of the International Bridge at Niagara raise Lake Erie?

A. I should say an inch, inch and a half, probably an inch and a half.

Q. You haven't accounted for this foot and a half yet.

A. No.

Q. Do you think that was caused by the dredging, etc., in the St. Clair River?

A. I think I am on record pretty fully on that point in this case.

Q. I know, but you have not taken that into consideration.

A. No, I think the effect of the dredging in the St. Clair River and Lake St. Clair and the Detroit River is a very little thing in accounting for the lowering of the lakes.

Q. But if the channels between Superior and Michigan-Huron, and Huron-Michigan and Lake Erie remained the same, the relations of falls between these lakes would have been the same?

A. Of course I take into account also the relationship between Erie and Michigan here and I find this falling of the lakes was a characteristic thing. It was not confined to Michigan-Huron, and was not confined to Erie; that the thing is in Ontario as well, so the dredging in the channels that you speak of, in the St. Clair and Detroit Rivers, which culminated in what has been called by Mr. Williams in this case, and I believe Mr. Stearns also, the sudden change in 1889 when the critical point was taken off the dam in the Detroit River, the Lime Kiln Crossing,—the same thing is occurring in Erie and Ontario, but we do not have any such critical dams removed in those lakes,—so this dredging, this taking away of the critical point which culminated in this lowering of 1889-90, these two years that have been rejected by Mr. Williams in his discussion, did not mean the increase in volume of flow passing through these other lakes, as far as I can make out, in an analysis; but we have the whole series of lakes, outside of Superior, at lower elevations in these later years.

You cannot charge that up to the dredging in the Detroit River and the St. Clair River and Lake St. Clair. An analyis of that indicates that the big bulk of the material removed was either outside the river, the bulk of it was outside the river in Lake St. Clair and Lake Huron, and that the portion that was dredged from the channels of the St. Clair and Detroit Rivers was, for the most part replaced, and additional material was brought in from other places and dumped in the St. Clair River and the Detroit River.

Q. There were certain improvements in the Niagara and also in the St. Lawrence Rivers, which affected Ontario, were there not?

A. Yes, but to my mind rather slightly. There has doubtless been some little lowering of Lake Erie through improvements, dredging of channels, but it is in my judgment very small. And the same is true of Ontario.

Q. Upon what did Mr. Noble base his testimony as to the effect of the lowering of Lakes Michigan-Huron, shown in Exhibit Number 1?

A. Mr. Noble based his testimony regarding Lake Erie on the observations made by—

Q. I asked as to Michigan-Huron?

A. Mr. Noble's testimony in that regard was as to the method employed of deriving the lowering, and I believe referred to U. S. Exhibit Number 1.

Q. In your recent testimony, you gave a value of 21,000 cubic feet per second for the St. Clair increment, did you not?

A. Yes.

Q. Then your earlier conclusions were in error? Is that a fact?

A. No, I think I gave a margin of possible error in the 21,000 as much as I did in my earlier testimony. I think my testimony was between 18,000 and 24,000 originally. The mean of those two quantities indicates 21,000.

Q. But your increment at that time was 23,800?

A. No, I think you are in error.

Q. Cubic feet per second, was it not?

A. No, I think you are in error about that.

Q. With an error of 25 per cent?

A. Reference to my testimony will indicate that I regarded the increment somewhere between 18,000 and 24,000 and the mean value between those appears to be 21,000; and the Lake Survey work is in confirmation of my conclusion at that time.

Q. You suggested that there might be an error either way of 25 per cent. in the St. Clair River?

A. I stated specifically my judgment was between 18,000 and 24,000.

Q. That is in the record. Now, Mr. Ray gave an increment of 20,700 cubic feet per second, did he not, for the St. Clair?

A. Yes, I would not quarrel with Mr. Ray about that other 300 cubic feet in the increment.

Q. Mr. Moore thought it might be anywhere from 17,000 to 22,000, did he not?

A. Mr. Moore in his testimony states: "I believe personally that the increment of the St. Clair River lies between 17,000 and 22,000."

Q. In your earlier testimony you stated your belief as to the possible effect of the diversion of 10,000 cubic feet per second was about five inches on Lake Michigan, did you not?

A. Well, no, I did not. I stated that U. S. Exhibit Number 1, indicated five inches. That would be for an increment of 24,000; but assuming an increment of 21,000, which appears to be the mean of the increments stated, it would be somewhat in excess of—a little less than six inches. An increment of 20,000 would give six inches for a diversion of 10,000.

Q. Mr. Noble stated the effect to be about five inches on Michigan-Huron, didn't he?

A. Mr. Noble testified from U. S. Exhibit Number 1, and took off the value of five inches, and his testimony is to the effect, as I understand it, that the method of deriving the lowering was a correct one, and U. S. Exhibit Number 1, showed that.

Q. He was asked to give his opinion, was he not?

A. Mr. Noble's opinion, as I understand it, would be based on U. S. Exhibit Number 1.

Q. Mr. Haskell, in his original testimony stated that the effect would be about six inches, did he not?

A. Yes, I think so. He used the International Waterways formulae or equations, which were independent of our own.

Q. And Mr. Wilson gave 6¼ inches on Lake Michigan?

A. That should be from the same data, and doubtless has to do with the different stage of the lake.

Q. And when Mr. Wheeler was asked his opinion, he gave 4.76 inches as the lowering?

A. Yes.

Q. For a diversion of 10,000 feet, on Lake Michigan?

A. I do not know,—we have still to look up what particular data Mr. Wheeler used.

Q. And Mr. Sabin stated that it was in his opinion from 5 to 7½ inches, did he not?

A. Yes, I remember the upper limit of 7½ inches used by Sabin.

Q. And Major Keller, gave five inches?

A. He used U. S. Exhibit Number 1, as the basis of his conclusion.

Q. But he was asked for an opinion, was he not, as to the effect of the diversion of 10,000 cubic feet?

A. Yes, as I recollect it.

Q. And he gave as his opinion five inches?

A. I may add that in the report of 1904, Mr. Thomas Russell would show it to be 6¼ inches, .52 feet.

Q. Mr. Russel has not been called by you?

A. He has been quoted by witnesses for the Sanitary District. His report is a thing that has been referred to frequently in the testimony.

Q. You did not consider Mr. Russell's opinion of sufficient value to call him?

Mr. Hopkins: Objected to as incompetent.

Q. Did you?

Mr. Hopkins: Mr. Shenehon does not call the witnesses in this case. It was entirely unnecessary; we had enough.

Mr. Adcock? Q. Did you?

A. I regard Mr. Russell's judgment as very good on many points, and I have taken issue with him as to his conclusion of the run-off of the Lake Erie watershed.

Q. Not even as an expert computer was he called, was he?

A. I prefer Mr. John F. Hayford as a man of wider international reputation.

Q. You were looking for a man of reputation?

A. Yes, a man who stands among the highest of any men engaged at the present time in physical investigations.

Q. That is your opinion?

A. That is my judgment; and I think it is an accepted judgment.

This does not appear to be clear, in so much of Mr. Wheeler's testimony as I have looked over here. He reaches an increment of 25,200 second feet in the St. Clair. That would indicate a lowering of the level of less than five inches, about 4¾ inches.

Q. 4¾ inches was Mr. Wheeler's opinion, was it not?

A. Yes, that is substantially the value.

Q. Mr. Moore, gave an opinion of about five inches, didn't he?

A. No. You mean in the original testimony?

Q. Yes?

Mr. Hopkins: I understood that all of this concerning what other people gave is based upon your recollection of what their testimony is.

A. Yes. The testimony will show for itself, I think. Mr. Moore arrived at his values after many more investigations

and many more observations, as recently stated, of between seventeen and 22,000 for the increment. An increment of 17,000 would indicate a lowering of about seven inches, and 22,000 would be 5⅜ inches. Those are the limits between which Mr. Moore in his later testimony—

Q. But in his original testimony, he stated the effect was five inches.

A. Well, his information is now very much more extensive.

Q. One hundred measurements more, isn't it one hundred more observations, something like that?

A. No, nearly twice as many as were had originally, not quite. There were 253 originally and 488 now.

Q. Mr. Ray stated that it was 5¼ inches, did he not?

A. That would be based on an increment of 22,000.

Q. Mr. Moore gave another value of 5 1/5 inches, did he not?

A. I do not recollect.

Q. Mr. Richmond gave the St. Clair increment as 22,700 cubic feet and the effect from that as 5.28 inches, did he not?

A. 5¼ inches.

Q. Yes?

A. I imagine you are stating these things in accordance with the testimony of the witnesses.

Q. Mr. Haskell, when last on the stand, gave a value of 18,900 cubic feet per second as the increment and the effect of the lowering at 6⅜ inches, did he not?

A. Yes, I believe he gave a value from the International Waterways report, which does not of course contain all the later data.

Q. Then, among the witnesses for the complainant who have testified upon this subject, there is a range from 4.76 inches by Mr. Wheeler from his own computations to 7.5 inches by Sabin, from his computations, with 5.7 inches as your testimony and 6 and 6⅜ inches Mr. Haskell's estimate, showing a range of 57½ per cent. in the estimated effect based on Mr. Wheeler's value. Is that correct?

Mr. Hopkins: Objected to as entirely argumentative, and on the further ground that the record speaks for itself.

A. I think the proper method of getting at a matter of that kind would be to take the mean value between extremes, which is 6⅛ inches, and make your percentage relation with respect to that.

Q. It is 57½ per cent. by Mr. Wheeler's value, isn't it, showing a range of 57½ per cent. by Mr. Wheeler's value?

A. Would you like me to figure that out?

Q. I am asking you the question. Yon can figure it out or guess at it or any way you want.

Mr. Hopkins: We will assume your figures are correct, if you state they are. That is the percentage based upon the iowest amount, what is it?

A. The difference between 7.50 and 4.76 is 2.74. Dividing that by 4.76 indicates 57½ roundly.

Mr. Hopkins: Q. What would be the percentage if properly computed from the mean?

A. If this percentage is computed from the mean, taking the extreme which is Sabin's 7½, and 6.1 as the average of the extremes, would indicate a percentage of 23 per cent.

Mr. Adcock: Will you read the question now, and I will ask the witness to answer it. I move to strike out his answer to the question as not responsive.

Mr. Hopkins: I put a question in there which was answered.

Q. (Question read as follows): "Then among the witnesses for the complainant who have testified upon this subject, there is a range from 4.76 inches by Mr. Wheeler from his own computations to 7.5 inches by Sabin from his computations with 5 inches and 5.7 inches as your testimony, and 6 and 6 3/8 inches according to Mr. Haskell's, showing a range of 57½ per cent. in the estimated effect based on Mr. Wheeler's value," is that true?

Mr. Hopkins: He has answered that question that it would be 57 per cent. of Wheeler's value.

Mr. Adcock: Q. Is that right?

A. Yes, I gave it in detail.

Q. It is 57½ per cent. as stated there. Is that right?

A. Yes, of Wheeler's computation, as indicated in my prior statement.

Q. Mr. Shenehon, has there ever been an occasion within your knowledge when discharge measurements were made at two different sections of the same river at the same time?

A. Not of the same river. We have made them in the same canal. That was done in the hydraulic power canal at Niagara Falls, and a similar process between what is known as the conveyor meter of one of the hydraulic sections in the Niagara Falls Power Company's canal. That was the method of comparing the precision of the sections.

Q. Are you familiar with the discharge measurements made under Col. Curtis MacD. Townsend, who formerly testi-

fied in this case, at Arkansas City, Arkansas, and Wilson's Point, La., in 1891 and 1892?

A. No.

Q. I refer you to a pamphlet compiled in the office of the Mississippi River Commission and printed under Government authority, entitled "Tabulated Results of Discharge Observations, Mississippi River and Its Tributaries and Outlets," pages 72 and 73 for Wilson's Point, and pages 65 and 66 for Arkansas City, and ask you to give the discharges there reported for Arkansas City and Wilson's Point for the period March 28th to April 4th.

A. How do you wish me to give this, individual dates and volumes of flow as indicated in this tabulation?

Q. Yes?

Mr. Hopkins: You are reading out of that pamphlet?

A. Yes, I am reading from the pamphlet referred to.

Date.	Arkansas City.	Wilson's Point.
March 28,	1,391,000	1,272,000
" 29,	1,419,000	1,288,000
" 30,	1,424,000	1,219,000
" 31,	1,409,000	1,201,000
April 1,	1,419,000	1,247,000
" 2,	1,406,000	1,276,000
" 3,		1,234,000

Q. The average there is 1,412,300 cubic feet per second at Arkansas City?

A. The average as indicated here in the computation made by Mr. Williams, for Arkansas City is 1,412,300 cubic feet per second, and for Wilson's Point 1,248,100, and the difference is 164,200 cubic second feet.

I, myself do not know the location of the two places nor whether the dates are coincident.

Mr. Hopkins: Q. Do you know anything about this work?

A. I know the volumetric measurements on the Mississippi River are not in the same class with the precision of the work in these clear fixed rivers of the Great Lakes.

Mr. Adcock: Q. These were current meter measurements, weren't they?

A. Yes, I made some statements in regard to the Mississippi River measurements in my cross-examination. In the Mississippi, with flood conditions, as I assume this must have been, there is an amount of grit and turbulence in the water that makes current meter measurements less precise than the results gotten in the clear waters of the Great Lakes.

Q. There was some precision obtained in these measurements, wasn't there?

A. I am not aware that the Mississippi River Commission attempts to work with any great degree of precision, for the reason that the river is fluctuating over very wide volumes of flow, and there appears to be no particular reason why they should get them down to the last refinement.

Q. At Wilson's Point, the average was 1,248,000 cubic feet per second, wasn't it?

A. As read.

Q. You say that they were not attempting to get close results. Is that true?

A. My understanding of the gaging of the Mississippi is that they do not work for any such precision as we have gotten in the rivers of the Great Lakes. The necessities do not exist for any such precision as that, and the difficulties are very much greater than any we had to contend with.

Q. You are familiar with the work called "Starling on Discharge of the Mississippi River"?

A. That is a paper that was read before the American Society of Civil Engineers, isn't it?

Q. Yes?

A. I would like a little information as to how far apart these two sections are, and whether the measurements coincide in every respect in time of day and so on, so that it may be in evidence.

Mr. Adcock: I refer you to page 371, of the transactions of the American Society of Civil Engineers for 1895 (volume 34), where it is stated:

"With all the precautions that experience has suggested, there are sometimes discrepancies or anomalies in discharge observations so great that they cannot be accounted for in any of the ways heretofore indicated. Instructive examples of this are to be found in the observations taken in 1891 and 1892 at Arkansas City and at Wilson's Point. Up to this time it had been impossible to check the observations at one point by those taken at another, owing to the intervention of tributaries, which introduced a disturbing element difficult to calculate. Thus Helena could not be checked by Arkansas City in 1884-85, because the White and Arkansas rivers poured out between the two stations a variable and unmeasured volume, which sometimes amounted to 300,000 cubic feet per second. In 1891, however, C. McD. Townsend, M. A. Soc. C. E., being dissatisfied like everybody else with the existing state of the

knowledge of discharges, had simultaneous gagings taken at the two places above named, 93 miles apart, and without any tributary or other disturbing condition between. The results showed the discharge at Arkansas City to be 150,000 to 200,000 feet more than at Wilson's Point. Had the difference been only for a day or two it might have been explained, well or ill; but it was continuous and persistent. At Arkansas City, from March 28th to April 4th, the records were 1,390,586, 1,419,422, 1,423,730, 1,408,553, 1,419,321, 1,405,641. At Wilson's Point they were: 1,272,440, 1,288,000, 1,219,436, 1,200,578, 1,247,445, 1,275,904, 1,234,182. Averages, 1,411,209, and 1,248,283. There was no crevasse or other disturbing influence between them. The same discrepancy kept up until April 23rd, after which date the difference slowly diminished. This unexpected result put the engineers to their wits' end. The meters were compared and exchanged. They had been several years in service, and their bearings were somewhat worn. They were rated frequently, and the rates of the same meter at different times were found to be very discrepant.

Captain Townsend considered the meters to be unreliable, and ordered two new ones. The next spring, 1892, a still greater flood developed, and high water discharges were taken at the same two places with the new instruments. The results were more discrepant than before. The discharges at Arkansas City from April 26th to May 9th, averaged 1,598,682; at Wilson's Point, 1,364,277. The instruments were compared, side by side, and meters and observers were changed, without affecting the result. There were no disturbing influences between the two places except the overflow of the foreshores outside of the levees, which increased only 1.7 feet during the interval of 13 days."

Then it takes up various explanations like, obliquity of current, vertical currents, other disturbing influences, the "flanking method," faults of method, etc.

What have you got to say now that you have heard the conditions under which the measurements were made there at Wilson's Point and Arkansas City?

Mr. Hopkins: I wish to object to this entire line of questioning, and this question in particular, because it is not proper cross-examination. The witness has not based any of his opinions upon the matter that has been read to him and therefore it is incompetent. I move that the question, and all this matter that has been read in, be stricken out.

Mr. Adcock: The witness is an expert measurer of dis-

charges, and I want to get his opinion as to these discrepancies that are found where they measure a river simultaneously at two different stations. That is something that was never done by the Lake Survey.

Mr. Hopkins: I want to object further on the ground that the witness states he has no personal knowledge of the work which was criticised by the author of the article read.

Mr. Adcock: Q. You know Colonel McD. Townsend, don't you?

A. Yes.

Q. He was one of the witnesses you produced in this case?

Mr. Hopkins: I object to "you produced"; let it be understood that the witness did not produce anybody; that the Government attorneys have run this case, and still insist that they are running it.

A. I am sure Colonel Townsend would object to being produced by anybody.

Q. I am assuming you are the General of this Regular Army, which Mr. Wilkerson spoke of in his opening statement in this case.

Mr. Hopkins: Objected to.

A. It is my recollection, as regards Colonel Townsend, that he testified as to the navigation of the Great Lakes; not the hydraulic question involved.

I take exception to the statement of counsel that we have not measured duplicate sections simultaneously. I have stated that we have; that we did in the case of the hydraulic power company at Niagara Falls, and that they checked within 2 per cent.

Q. I am speaking of the measurement of rivers.

A. The flow in an open stream, whether artificial canal or river amounts to the same thing, and demonstrates the validity of the results.

I wish to state further we observed under identical conditions as to the elevation of Lake Erie, for instance, in the Niagara River, on three different sections and we have checks within one, 1.3 and ½ per cent. That is a sufficient answer.

As regards the Mississippi River work, I should wish to know the whole personnel of the men handling the instruments, the methods used, the current meters used; all the conditions. If these are placed in my hands, including the observations themselves, and their methods of reduction, I should be very glad to pass on the conclusions.

Q. You were ready to accept the conclusions of Mr. Sabin without very careful study?

A. Yes. I know something of Mr. Sabin's methods, and I know the instruments he used. I know his equipment. I know the care used. I know the months over which the work extended. I know the clarity of the river in which he had to work, and know the permanence of conditions with which he had to deal; and I know that the Gorge Section which was measured in the St. Clair under my supervision as Principal Assistant, checked Mr. Sabin's work within 1 per cent.

I know that the Delta Section checked again within 1 or 2 per cent, so I have every reason for confidence in the work on the St. Clair River.

Q. You are not so familiar with the work of Mr. Townsend?

A. Mr. Townsend doubtless never handled —

Q. I beg your pardon, Colonel MacD. Townsend.

A. I feel very positive that Colonel Townsend handled none of the instruments; did none of the field work, and if he followed the procedure of engineer officers, it was pretty largely in the hands of his civilian assistants.

Q. You have confidence in civilian assistants, haven't you?

A. Not necessarily.

Q. Particularly where they are under the direction of army engineers?

A. Before you asked that question, I made certain statements regarding the Mississippi River—

Q. The Mississippi River also is a very large river, is it not?

A. Yes, that in a very few days measured a volume of flow five or six times, eight times bigger than the flow measured by us in many months.

Q. According to your theory, the larger the river the more accurately the discharge could be measured with the current meter? If that is so, they ought to have gotten within about 1/16 of 1 per cent.

Mr. Hopkins: The witness stated, if sufficient work were put upon it.

A. That is hardly a fair conclusion in itself, that the whole thing is dependent upon the size of the river.

Q. Now there are some diversions at Niagara Falls, aren't there?

A. Yes.

Q. There is a treaty between the United States and Canada, is there not, with reference to that?

A. Yes, Great Britain and the United States entered into a treaty—

Q. The Canadian power companies may divert 36,000 cubic feet per second?

A. Under the treaty, a limitation of 36,000 is placed.

Q. And on the American side there is a limitation of 20,000?

A. Yes.

Q. It is generally understood that that difference of limitation, or the less amount for the American companies, was because of the diversion at Chicago, the contemplated further diversion, is it not?

Mr. Hopkins: Objected to. The treaties speak for themselves; it is incompetent.

A. I have no evidence of that fact.

Q. It is a general feeling, is it not, that perhaps if the diversion were limited, the diversion at Chicago were limited, the American power companies might receive more water.

Mr. Hopkins: I object to the question in regard to the general feeling. Ask him as to his own feeling.

Mr. Adcock: The general understanding?

A. I do not think so. Let me perhaps clarify this a little.

Q. If you don't know anything about it, just say so.

A. I am going to say something concerning it. The American channel contains about five to seven per cent. of the total flow of the river. The International boundary is in the main rapids, and fairly close to Goat Island, so that probably 80 to 90 per cent. of the volume of flow is on the Canadian side of the boundary.

At Sault Ste. Marie, the bulk of the flow is on the American side of the boundary, and as I have understood those two facts were taken into consideration in adjusting the volume of flow at Niagara; 36,000 for the Canadian and 20,000 for the American companies.

Q. Now, you have been retained by the Hydraulic Power Company, have you not?

A. Yes, I was retained—I was engaged by the Hydraulic Power Company in the beginning of 1912, I believe it was.

Q. That is an American company?

A. Yes, that is the big American company, that has a head of 210 feet going over the bluff.

Q. You were retained, and under that engagement you

wrote a communication to what is known as the Special Board of Engineers on Waterways from Lockport, Illinois, to the mouth of the Illinois River, which had under consideration compensating works, etc., did you not, Mr. Shenehon?

Mr. Hopkins: I object to the question as not proper cross-examination; and we do not intend to have any matters in regard to compensation come into this case through our witnesses. It is a matter that involves an appropriation from Congress, whether it is large or small, and therefore it is not proper to be considered in this case. I instruct the witness not to answer.

Mr. Adcock: I have not asked him anything about compensating works.

Mr. Hopkins: You asked him if he wrote such a letter.

Mr. Adcock: I asked him if he wrote such a letter.

Mr. Hopkins: I instruct him not to answer.

Mr. Adcock: I am asking him with reference to a letter which he wrote to a Board which had under consideration that matter; and I want to say that this question has nothing to do with the compensating works. However, we do insist that the question of compensation is an important element in this case, but I am not asking the witness to—

Q. Did you write a letter on behalf of the Hydraulic Power Company of Niagara Falls, on October 12, 1912, to the Board of Engineers on Lakes to the Gulf Waterways?

Mr. Hopkins: That is all right.

A. I appeared before the Board of Engineers—

Mr. Adcock: Wait a minute.

Mr. Hopkins: The question is did you write such a letter?

Mr. Adcock: By this question, I do not wish to withdraw the question which I asked, which counsel has instructed the witness not to answer. I insist upon the witness answering the question which I asked him. At the proper time, I will take such advantage of counsel's instruction as may seem proper in this case.

Mr. Hopkins: I still instruct the witness not to answer the original question. In regard to the second question, whether he wrote a certain letter at a certain time, he may answer yes or no if he cares to.

A. Yes.

Mr. Adcock: Q. You wrote that letter did you not in behalf of the Hydraulic Power Company?

A. Yes.

Q. You didn't mention, when counsel asked you as to addi-

tional qualifications which you might have to testify in this case, you didn't make that statement—

Mr. Hopkins: Objected to.

Q. —make the statement as to the fact that you were employed by the Hydraulic Power Company since you testified in this case, did you?

Mr. Hopkins: It appears what he said.

A. I testified that I had a practice as a consulting engineer, which included that and other engagements not mentioned.

Q. You mentioned various engagements you had, did you not?

A. I mentioned when specifically questioned one engagement; that was my retention as expert in the case of the United tSates v. Chandler-Dunbar Company, and also the case of United States v. Sanitary District of Chicago.

Q. But you did not mention this particular employment?

A. No. Under advice of counsel.

Q. You did not mention it?

A. Under advice of counsel.

Q. Under advice of counsel. What did counsel say to you?

A. That the question of compensation would be objected to as immaterial, and therefore it would be well not to bring the matter in by specific reference to the thing.

Q. But you went into certain questions that had to do—

A. Let me add something more: I was very well aware of the fact that this pamphlet was in your hands at the time; and the fact of my service for the Hydraulic Power Company is a well-known one.

Q. Mr. Shenehon, there were various considerations, various matters which you took up in that letter which had to do with hydraulic questions, did they not?

A. Yes.

Q. And perhaps the study which you made in connection with the engagement for the Hydraulic Power Company might have additionally qualified you to testify in this case?

Mr. Hopkins: That is objected to. It is a question for counsel to determine as to what qualifications they desire to bring out.

Mr. Adcock: Q. Now when did you have this conversation with reference to this particular letter?

A. You mean with counsel?

Q. With counsel, yes.

A. I believe that was on Tuesday, April 14th.

Q. That was just before you testified in this case, was it?
A. Yes, just before my testimony. I testified on the 15th.
Q. With whom did you have that conversation?
A. With Mr. Hopkins and Mr. Wilkerson.
Q. This particular letter was discussed, was it?
A. Yes.
Q. Both letters?
A. The second letter was not presented on behalf of the Hydraulic Power Company.
Q. Whom was that presented on behalf of?
A. On behalf of myself.
Q. Did you consider that the letter you presented on behalf of yourself was in any way inconsistent with the employment indicated in the letter you presented on behalf of the Hydraulic Power Company?
A. The Hydraulic Power Company does not approve of any scheme of regulation in which movable gates of that form are used.
Q. Your second letter did not detract from the effect of the first letter, did it?
Mr. Hopkins: Objected to.
A. That I don't know.
Mr. Hopkins: He does not know.
Mr. Adcock: Q. What?
A. I do not know.
Q. It would be rather peculiar for you to write a letter on behalf of the Hydraulic Power Company advocating certain things, and then write another letter on behalf of yourself, which was inconsistent with the letter you wrote on behalf of the Hydraulic Power Company.
Mr. Hopkins: I object to the statement of counsel as purely argumentative.
A. I do not believe there is any inconsistency between the two, so far as that is concerned.
Q. If the second letter was of any benefit to the Hydraulic Power Company, you were perfectly willing that benefit should be obained by them, were you not?
A. Sure. The second letter presented a scheme that I believe is beneficial to all three elements considered; that is the power companies and the scenic grandeur at Niagara Falls, and navigation, with all three of which I have had to do.
Q. Do you consider that your employment by the Hydraulic Power Company has in any way increased the interest you have in behalf of the Government in this case?

A. I think a comparison between my evidence in 1909 and my evidence later will indicate that.

Q. I note that you used—

A. That my point of view is substantially the same now as then.

Q. You used very extravagant terms at different times in the course of your re-direct examination, in criticising the work of Mr. Williams and other witnesses in this case, that their conclusions were erroneous, and not based on good engineering tactics or principles, etc., and I wondered if your interest had anything to do perhaps with the language which you used concerning the conclusions?

A. No, I did not have a chance earlier to characterize some of the methods used by the experts, Mr. Williams in particular for the Sanitary District. My language, I think, might have been the same earlier, under like circumstances.

Adjourned to Monday, May 18, 1914, two o'clock P. M.

Monday, May 18, 1914,

2:00 o'clock P. M.

FRANCIS C. SHENEHON, resumed the stand and testified further as follows:

Re-direct Examination by Mr. Hopkins.

Q. Mr. Shenehon, in your cross-examination you testified that the local supply of Lake Erie for the open season was about 3 per cent. of the Niagara discharge. What percentage is the local supply of Lake Erie for the whole year?

A. Based on the run-off values given by Mr. Gardner S. Williams in Table LIX A, of his Exhibit 34, the run-off for the full year is given as 0.664 cubic second feet per square mile of drainage area. That is the dry land portion of the drainage basin. Taking the area of the dry land tributary to Lake Erie and St. Clair as 30,300, this indicates a yield of 20,100; and this is 9.14 per cent. of a flow of 220,000 cubic second feet.

Q. What percentage of the entire drainage basin of Lakes Superior, Michigan-Huron and Erie, including the water surfaces is the drainage basin of Lake Erie, including the water surface?

A. 16 per cent.

Q. And Lake Erie has a notoriously small run-off in comparison to its size, in comparison with the other lakes, has it not?

A. Yes. Another point comes in there in the presumably greater evaporation of Lake Erie, so that we can possibly get no yield from the rainfall in the water surface, while on the upper lakes there is a possibility of receiving some yield from the rainfall on the lake surface itself.

Q. I show you a chart entitled: "Elevation of Niagara River, Chippewa gage," which I will ask to have marked Shenehon's Exhibit V. I offer the chart in evidence and ask you to tell what it is; who made it and what it shows?

(Chart so offered in evidence by counsel for Complainant, was here marked Shenehon's Exhibit V.)

A. This is a chart in which the hourly elevations of the water surface of the Niagara River at the Chippewa gage are plotted in the vertical for elevations and the hours in the horizontal.

The tracing cloth or sheet on which this is plotted is graduated, so that each hour may be indicated, and each tenth of a foot and half tenth of a foot are indicated by the vertical scale, so that the elevations may be plotted one one-hundredth of a foot. The dates are given across the top of the chart, showing that the chart begins on October 21, 1907, and continues on the top line through November 6.

Q. Were those the same dates in regard to which you were cross-examined?

A. No. The date on which I was cross-examined was November, 1906, as I recollect; the first few days, first to sixth inclusive, in 1906.

A second line is plotted in the form of a series of dots, forming a dotted line that follows along the solid black line; the solid black line being the elevations, the observed elevations at the Chippewa gage. The elevations shown by the dotted line are computed from the observed elevations at the Buffalo gage for the several hours concerned, assuming a lag of two hours. This computation is made by using an equation which is indicated on the chart.

Q. What is that equation?

A. The equation is $H_C = 561.23 + .557\ (H_B - 570.00)$.

Mr. Adcock: Will you translate that into English?

A. In this equation, H sub C is the height at the Chippewa gage, and is so stated on the chart. H sub B is the height

of Lake Erie at the Buffalo gage, and the elevations are in feet above sea level.

The first term of this equation, 561.23 indicates the elevation at Chippewa when the Buffalo gage is 570. Then as the Buffalo gage varies, for instance when it rises a foot at the Buffalo gage, it rises .557, or at that rate.

Mr. Hopkins: Q. You do not mean the Buffalo gage rises .557, you mean the Chippewa gage?

A. The water surface at the Chippewa gage rises .557. In other words the movement at the Chippewa gage indicated here is 55.7 per cent. of the movement at the Buffalo gage.

Mr. Adcock: Q. That is the purpose of the equation, isn't it, to show that?

A. Yes, that indicates the relative elevations of the water surface at the two gages. The lower line contains similar information for the days June 26th to July 12th, inclusive of the year 1908.

This chart was made under my direction in November, 1913, in investigating the relationships of the water surface elevations to the fluctuations.

Mr. Adcock: Q. Did your assistant have anything to do with it?

A. Yes, this was made under my direction by my assistant.

Q. That is the same gentleman you spoke of the other day?

A. Yes, his name appears as delineator on the chart, Mr. M. E. Souther. The statement is made on the chart that the lag used is two hours, and this chart in its designation is indicated as "Studies in River Hydraulics."

There is also an accentuated scale of inches, to assist in understanding the relations of the two curves shown.

Mr. Hopkins: I ask that that be marked Shenehon's Exhibit V of this date.

(Document previously so marked.)

Q. Have you made any further checks or computations showing the correspondence between the Buffalo gage and the Chippewa gage, taking daily means? If so with what result?

A. I have made an investigation, in which I have examined the relation between the elevation of water surface at Chippewa with respect to the elevation of the water surface at Buffalo gage. This was done by taking five hour periods at each of the gages, taking Chippewa gage three hours later than the elevations at the Buffalo gage.

Q. What was the result of that, in respect to whether you can predict the elevation at Chippewa, and how closely?

A. I chose the month of November, 1907, for this investigation, and took the first ten days. My object in chosing the month of November was to obtain what is the worst month of the year so far as storm conditions are concerned, and variation of the surface of Lake Erie. It will give a very excellent test of the relationship under the most adverse circumstances of wind and storm and barometric gradient.

Mr. Adcock: Is that November 1st, to 10th?

A. Yes, November 1st to 10th inclusive.

I chose the year 1907 for another reason. That was that I wanted to use an equation which was derived from a different year, so that the charge of "circular reasoning," I believe it has been called in this case, could not be made. In other words the equation was that of the year 1906, while the observations were those of the year 1907, which were not used in deriving the equation.

Q. You wanted to be relieved of any accusation that you were reasoning in a circle, is that it?

A. Yes. This gave forty individual sets of five hours each, and the mean of those indicates that in three cases we have exact agreement. In other words, the prediction of the elevation of the water surface at Chippewa from the Buffalo gage is exact, and in 12 cases the agreement between the predicated value and the actual value is ½ inch or less. In 21 cases of the 40, the agreement is within one inch or less.

In 30 cases out of the 40, the agreement is within 1½ inch or less; and in 38 cases out of the 40, the agreement is within 2 inches. And the largest discrepancy is 2.7 inches.

During this period we had a range of elevation in Lake Erie from 572.18 to 574.14, or a little less than 2 feet.

Now it would not be fair to let the ability to predict the elevation at Chippewa from the Buffalo gage rest on possibly the worst month in the year, and so I have taken also a series of readings in the month of August, 1906. In these readings, we cannot escape the accusation of circular reasoning, that could not be applied in the other case.

Mr. Adcock: Q. That was August? What days?

A. I was just about to state that. As the first and second days are incomplete in the record of the Chippewa gage, I began with the third day of the month and took the dates August 3rd to 12th inclusive.

There are 40 predictions in this series, each—

Q. That was five hour mean?

A. Yes, these are five hour means, with the same lag of three hours. The prediction was exact in four cases out

of 40. It was within one quarter of an inch in 16 cases out of 40.

Q. Within ½ of an inch?

A. Within ½ an inch in 27 cases out of 40, and within 1 inch in 37 cases out of 40. The greatest discrepancy, a single discrepancy, is two inches.

Now if we take the means of the 20 hours on each particular day—

Q. What was your range in this case?

A. The range of Lake Erie, as indicated by these sets of means of five observations is from 572.11 to 573.15, or a little over one foot.

Q. These ranges in both cases were for five hour means?

A. Yes. They are not the extreme ranges of the lake.

Q. You said something about the 20 hours?

A. Yes. I was about to indicate the closeness of the check where we consider the means of the 20 hours for each day.

For the month of August, in four cases out of ten, the check is exact, the prediction was exact. In nine cases out of ten, the prediction is verified in the observed values at Chippewa within ½ inch and in one case the discrepancy is a little less than one inch, approximately one inch.

I made a similar investigation of the 20 hour periods for the month of November. This indicates that six predictions out of ten are less than one inch discrepant, the maximum discrepancy being 1¾ inches.

Q. If you had taken 48 hours it would have been closer, would it not?

A. Yes. The longer the period within limits, of course the more closely the lower gage will correspond with the upper gage, although the 20 hour periods appear very accordant.

Mr. Hopkins: Q. You have never contended, or tried to make those gages check for a less period than daily means have you, so far as this case is concerned?

A. In the computations deriving the values as indicated by the equation which I read, the daily means were used; that is individual observations, as I recollect it.

Q. In your opinion, what is the value of a check by using individual observations between the Buffalo gage and the Chippewa gage?

A. It shows that for approximately half of the ten hour day which may be regarded as the working day—

Q. I say individual observations?

A. You mean single, hourly?

Q. Yes?

A. There is not any necessity, as I see it. We have discrepancies for single hours.

Q. How do you explain those discrepancies?

A. That comes from the fact that when Lake Erie is rising, for instance, fairly rapidly, a portion of the outflow caused by that rise is used in filling up the river between Buffalo and Chippewa, and that means that the full volume of flow does not immediately reach Chippewa. And when the lake is going down we have the converse condition entering. The Chippewa gage is still discharging the water accumulated in the river by the higher lake stage, so in that case we have the residual of error of the opposite sign.

Q. It is hard to tell just when the crest has reached Chippewa, is it not? It is more rounded than at Buaffo, as indicated by that chart?

A. Yes, this chart shows very clearly that in the determination of the lag, for instance, between Buffalo and the Chippewa gage, the roundness or flatness of the crest at Chippewa makes the task a more difficult one than where the movement of the water is greater and the crests are sharper.

This is very well illustrated on November 3rd, where a well marked peak appears from the computed Buffalo gage, and a rounded elevation shows for the Chippewa gage. One might choose through a range of at least three hours the crest at Chippewa corresponding to the crest at Buffalo; and where the movement is less pronounced than it was on that day, as it was nearly a foot there, the difficulty appears from an inspection of this chart.

Q. In other words the changes at Chippewa are not so extreme but last longer. Is that not true?

A. Yes, there is a tendency to a little greater stability there than indicated by the movement at Buffalo.

Q. Also in taking hourly observations, can you tell just when the highest point has reached a particular gage?

A. There is a difficulty coming in from the fact that between the hourly elevations there may be a slight rise in the Buffalo gage, for instance, that does not appear in this record, between the even hours, so that we may not in the hourly scalings get all the actual peaks or all the actual valleys that really occurred.

Q. So that in your cross-examination, when you were asked to pick the next crest or the next valley after a certain elevation or depression at Buffalo, you can only get those on the hour, and there might have been one that happened in

the meantime that would not appear in the evidence, is that right?

A. Yes, that is true. I think the difficulty of predicting in the way in which the matter was put up in the cross-examination appears from this sheet; where we take a great many dates and a great many observations, we can get a sufficient number to reach,—not a prediction, but a statement of the lag.

Q. Did you include that matter in what you termed error of observation, that is you were only observing once an hour, or rather taking observations once an hour?

A. Yes, that was intended to be covered by that term; that it had to do with all the elements that might cause in a particular instance an erroneous result for the lag; and in the end, you understand, the lag—

Mr. Adcock: Q. Those were hourly means, were they not?

A. No, they are hourly scalings, just as if a man were at the gage—

Q. I know, but on this exhibit, Williams' Exhibit whatever it was—

A. No. Those are actual individual scalings of the gage roll. They are not hourly mean elevations. It is just as if a gage tender visited the gage once an hour and got what the water surface was at that particular time.

Q. On this automatic gage?

A. The gage rolls are graduated in hours, and simply the elevation of the water surface where this graduation comes is scaled off and the mean of the 24 hours of the day gives the mean elevation for the day.

Q. But the peak any time within the hour would be shown on the roll, wouldn't it?

A. Yes.

Q. And that is what you are supposed to read?

A. Not in this investigation, as I pointed it out to you.

Q. You read it for a certain hour?

Mr. Hopkins: Q. Just what it would be at ten o'clock sharp, eleven o'clock sharp.

A. (No response.)

Mr. Adcock: Q. Is that what is read out, ten o'clock or eleven o'clock?

A. That is the point, just as if we did not know what was in between the hours. They are simply the elevations at these hourly periods.

Mr. Hopkins: Q. Does that same situation apply in re-

gard to the two Gorge Sections, that is the Whirlpool and the Suspension Bridge?

A. Yes, with this exception, that the movement of the water is so much bigger there that the peaks and valleys appear very much better accentuated, so that it is a simple task to determine the lag, and yet we have this other thing that you mentioned, this fact that at Buffalo there may be a peak which is sending down water at the half hour, for instance, and which appears on the scaling of the gage at Suspension Bridge and the Gorge, and does not appear on the Buffalo gage as from the hourly scaling, you understand that condition still obtains, so individual observations are subject to the small errors coming from that.

Q. In other words there may be peaks or valleys that pass Suspension Bridge or Whirlpool that are not in the record which was used in the cross-examination of you?

A. Yes.

Q. The elevations at Suspension Bridge and Whirlpool were also taken at one hour periods, and not as hourly means?

A. Yes, that is a general principle in scaling these gage rolls, for the preparation of the sheets similar to the one that Mr. Williams presented to me, or Mr. Adcock presented to me in the cross-examination on Saturday.

Q. Then in those questions that were asked you in regard to a peak, wherein counsel stated that a peak appeared at Whirlpool two or three hours before it did at Suspension Bridge, it might have been a different peak entirely, so far as that one case would indicate?

A. Yes. There is that chance, and that was considered among the errors of observation.

Q. Mr. Shenehon, would you agree with Mr. Williams in the following testimony given by him on cross-examination in this case: (Typewritten page 1222-354, printed page 897.)

"Q. That is to say from the mean elevation at Buffalo you have been able to predict the Chippewa gage within substantially a quarter of an inch?

"A. That is correct. * * * It indicates the establishment of a relation with a satisfactory degree of precision, so far as gage elevations are concerned.

"Q. And I understand that the period covered is 11 months?

"A. Yes." Would you agree with that, the parts that I have read?

A. Yes, the 11 months refers to the prediction from the

Cleveland gage which Mr. Williams was able to make with considerable precision, mostly within 1 inch.

Q. The two questions were referring to different gages?

A. Yes, the daily means with respect to the Buffalo gage and the monthly means with respect to the Cleveland gage.

Q. You stated in your cross-examination that in the ultimate result you did not think it made any substantial difference in deriving an increment for the Niagara River whether or not you allowed eight minutes for lag from the Buffalo gage to the International Bridge. Will you explain a little more in detail why that is so?

A. Whether we take the water surface elevation at Buffalo gage for a period of ten minutes preceding our observations or ten minutes after would have substantially no effect on our final conclusions. It may make the discrepancy of an individual observation a little greater.

I may say also if we should extend that under ordinary conditions, and were in error in our lag by an hour that we would introduce into the final result, in my judgment, no substantial error.

The individual observations in that case would show a little more discrepant and in examining the discrepancy of the observations themselves we have a measure,—we could charge up to the gage entirely the discrepancy and it would indicate that it is very small.

Q. Why not?

A. Because the lake in the most cases does not change largely in a period of an hour and sometimes the change is a little rise and sometimes the change is a little fall. Of course individual cases where the change is charged to the incorrect lag, in that case would show in a discrepancy; the individual observation would plot off from the line.

Q. So that in a great number of measurements of observations, it would practically give you an elevation of the lake remaining stationary long enough for your observations or your measurements, discharge measurements?

A. Yes, that is true.

Q. Well, how about a period of four or five hours or twelve hours or more?

A. When you get much beyond an hour, you are beginning to introduce errors that will show very large discrepancies and may in the end affect the substantial accuracy of your increment. And in the case of 10 to 12 or 24 hours of course

you have reached a condition where you might have very discrepant results.

Q. In your opinion, what percentage of the time it takes the lag to travel from Buffalo gage to Chippewa, does it take for it to travel from the Buffalo gage to the International Bridge at Buffalo?

A. My view of the lag at Chippewa, is, as I stated, somewhere between two hours and 15 minutes and two hours and 40 minutes, and the lag at the International Bridge is from eight to ten minutes.

Q. The 17 per cent. that you gave on cross-examination was simply an answer to the hypothetical question there given you?

A. Yes.

Q. And that was based upon a rough approximation of depths, as you took them from the chart?

A. Yes, it is utilizing a formula in conditions that may be quite different from those in which the formula was derived. That is the Niagara River varies considerably in depth from the International Bridge to Chippewa, and this appears to make the application of the equation or formula somewhat erroneous.

Q. You stated in your original testimony that you some years ago computed an increment for the St. Lawrence River of 28,900. I believe it was pointed out that there should be a correction of 5½ per cent for the effect of the Gut Dam and 2 per cent. for the change to the Oswego gage?

A. Yes, from the Ogdensburg gage.

Q. Are there any other reasons why you are willing to adopt the new increments suggested by the Lake Survey and testified to by you in your rebuttal testimony?

A. Yes.

Q. What are they?

A. The greater range secured in the later observations have some bearing on that; and as I stated, earlier, an investigation by the method of fluctuations indicates somewhere in the neighborhood of 19,000 for an increment, which tends to verify the later results of the Lake Survey.

Q. Also there are more observations?

A. Then the other thing, the weak point in the original increment was the small range secured, in the neighborhood of two feet.

Q. Also you have many more observations, have you not?

A. Yes.

Mr. Adcock: Q. How many?

A. I cannot state that without looking it up.

Mr. Hopkins: I show you a chart marked Shenehon's Exhibit D1, of this date. What is the chart, by whom was it made and what does it show?

(Chart referred to was here marked Shenehon's Exhibit D1, May 18, 1914.)

A. This is a chart which is similar to Shenehon's Exhibit D, of April 15, 1914, in the matter of graduations for elevation of Lake Erie and the horizontal graduations for volume of discharge, and in other respects that are apparent on inspection.

This is entitled: "United States vs. Sanitary District of Chicago; Discharge Measurements of the Niagara River Plotted from the Records of the U. S. Lake Survey, Open Section, Buffalo, New York. 89 measurements selected by Mr. Gardner S. Williams, Expert witness on behalf of the Sanitary District from a total of 121 measurements in 1899-1900, shown thus." And on this chart it is stated that the increment used by the United States is 21,640.

The object of this chart is to show the observations taken under quiescent conditions as selected by Mr. Williams will give an increment for the elevations corresponding to the volume of flow for individual observations taken from the records of the United States Lake Survey an increment as determined by the United States namely 21,640.

The heavy black line threading these observations represents the law of discharge 21,740, used by the United States in Exhibit Number 4, U. S. Exhibit Number 4.

In further explanation of this chart, I desire to state that the 89 observations are plotted exactly the same as the observations are plotted on Shenehon's Exhibit D, of April 15, 1914. The only difference between those two so far as the plotting of the observations is concerned is that the number is 89, and these are selected observations instead of the full 121 plotted on Shenehon's Exhibit D.

Mr. Adcock: Q. Have you taken the elevation for a period or just for the time?

A. I will state further, the elevations and values are those appearing in the tabulations of the observations which have already appeared in this case, prepared by the United States Lake Survey.

Q. Does the diversion of water by the Power Companies at Niagara, divert it permanently from the Great Lakes?

A. No. The water is diverted, in the case of the American Companies, above the Cataract Rapids and returned to the

Niagara River in the Gorge, and goes on down the Niagara River into Lake Ontario and remains in the system of the Great Lakes.

Q. How much navigation is there between the intakes and the point where it is returned to the Niagara River?

A. In the case of the American companies, boats run as far as Port Day, which is the entrance of the lower canal, the Hydraulic Power Company's canal, which is a few hundred feet below the intake of the Niagara Falls Power Company.

Q. What size of boats?

A. Small boats only, tugs and scows and vessels of that character. I may add that what is known as the dead line extends from Port Day, which is the entrance of the Hydraulic Power Company's canal to Chippewa, and below this dead line navigation does not venture. When I say that, I presume in dumping the scows, there have been cases where they dropped below the dead line.

Q. This navigation that does go as far as Port Day, what is the draft of the boats?

A. Not over 15 feet.

Q. What is the depth?

A. Depth of the water itself?

Q. Yes?

A. The limitation is, I believe, to 14 feet. I am not certain they can carry 14 as far as this point.

Q. Do you know what effect there is on navigation by virtue of the diversions at Niagara; if so what?

A. There has been a lowering caused by the diversions of the power companies at Niagara Falls, the two American companies and the Ontario Company which takes its water from the head of the Rapids or a little ways down in the Rapids. Investigations however indicated that the divertor of the Ontario Company had nearly compensated the lowering. Assuming that there was a diversion at Niagara Falls of 20,000 cubic feet, the corresponding lowering—

Mr. Adcock: Q. There is some from the Canadian side, is there not?

A. The diversion on the American side is limited to 15,100.

Q. What is the Canadian diversion?

A. I am assuming that to be about 5,000 in the Ontario Company. That is the only one that has any effect whatever on what is known as the Grass Island Pool. The Ontario Company is the only Canadian Power Company that affects the elevation of water in the pool to which we have been re-

ferring; that is the water in the navigable portion of the river.

Mr. Hopkins: Q. What effect does it have on navigation, what ships are likely to be affected so far as navigation is concerned in the Niagara River?

A. There is very little navigation in the Niagara River below Tonawanda which is some distance up the river. There is, however, a sufficient amount of navigation so that the Federal Government is in control of the diversions at Niagara Falls.

Mr. Adcock: I object to that; and move to strike out the answer as it is not responsive to the question; states a conclusion, and is improper for the witness to give such a conclusion.

A. The lowering caused by a diversion of 20,000 cubic second feet in this pool would be a little over half a foot, .51 of a foot.

Mr. Hopkins: Where?

A. At Chippewa and the Grass Island gages immediately above the rapids.

Q. Chippewa is below this diversion, isn't it?

A. Chippewa is across the river from the American Power Canals and above the Ontario Company's intake. I think you understand that the diversions at Niagara Falls have been permitted and limited by Congressional action, and the permits from the Secretary of War.

Q. You have a letter from Major Keller that you wanted to submit here?

A. When the Hydraulic Power Company in December, 1911, asked me to undertake certain investigations for them, I was a little in doubt as to the propriety of doing the work for a power company, after having made the investigations of all the conditions for the Federal Government and having made recommendations to it.

I may state, however, that the power company wished me to carry out for them certain recommendations as to ameliorating works made in my report which is known as the report on the Preservation of Niagara Falls. So I wrote to my friend and my superior officer in the Lake Survey.

Mr. Adcock: At that time you were not connected with the Lake Survey?

A. No, this was in December, 1911. It was something over two years after I had severed my connection with the Federal Government. So I wrote Major Keller, asking his views on this and he replied as follows, I put this letter in evidence:

United States Engineer Office.
"Rock Island, Illinois,
December 28, 1911.

Mr. Francis C. Shenehon,
Dean, College of Engineering,
University of Minnesota,
Minneapolis, Minn.

Dear Shenehon: I have yours of the 28th, and am sorry that you cannot join us on the Panama trip. Perhaps at some later day we may be able to get together on some similar undertaking.

In the meantime, I wish to answer your inquiry as to whether in my op'nion there is any reason why you should not undertake the commission offered you by the Hydraulic Power Co. While I have some hesitation in offering opinions concerning questions that after all each man must decide in the light of his own conscience, this case seems so clear that I give you my opinin for the little that it is worth. There is in my mind not the slightest doubt that you are fully at liberty to accept the commission which has been offered to you. Your previous official knowledge of the matter will enable you to do fuller justice to the United States in case any interest of the United States should be involved, and I feel sure that should such interest become evident, you will be amply able to devise means of reconciling the private with the public good. It is an advantage to the United States to have someone with really expert knowledge of all the considerations involved to handle a matter of this kind, and I therefore feel free to wish you a long and successful engagement.

Very sincerely yours,
C. Keller,
Major, Corps of Engineers."

Mr. Adcock: I wish to object to the introduction of that letter in evidence, on the ground it is entirely immaterial; it is incompetent and has no place in determining any of the questions involved in this suit.

The Witness: I wish to make a further statement concerning this letter, that Major Keller was Officer in Charge of the Lake Survey, at the time the Chicago Drainage Canal case was initiated, and it was through his recommendation that I have been continued as expert for the Federal Government in this case. So he has full knowledge of all the elements entering into my employment and I regard his advise as very sound, excellent.

Mr. Adcock: I move that the further answer of the witness be stricken out as immaterial and incompetent.

Mr. Hopkins: Q. Mr. Shenehon, does the fact that you have been employed by and are in the employ of the Power Company have any effect upon your testimony in this case?

Mr. Adcock: I want to object to that question as it is not competent for a witness to state what interests he may have in a law suit; conclusions in regard to what may affect his testimony. That conclusions is to be drawn from the facts. It is entirely improper on re-direct examination, or in any event, to ask a question of that kind.

Mr. Hopkins: You went into the question of his interest. No one knows about that better than he does.

Mr. Adcock: You cannot ask him a conclusion as to his interest. You can ask him the questions and bring out the facts.

Mr. Hopkins: Answer the question.

A. Not in the least.

Mr. Adcock: I move that the answer be stricken out.

Mr. Hopkins: Mr. Shenehon, in your opinion, would a diversion at Chicago cause any material effect on the Great Lakes?

Mr. Adcock: I want to object to that on the ground that it is incompetent, immaterial and irrelevant. It is improper to ask the witness a question which may be the issue in this law suit, or which involves one of the issues in this law suit; ask him a conclusion as to the ultimate fact or an ultimate fact. It is an attempt to invade the province of the court. That is for the court to determine from all the facts which may be presented.

Furthermore it is improper on an examination of this witness at this time in so called rebuttal.

Mr. Hopkins: I did not give you the amounts: Suppose 2,000, 4,000, 10,000 or 14,000 cubic feet per second?

A. The diversion as mentioned would unquestionably, in my judgment, have a substantially detrimental effect on the Great Lakes from the lower entrance of the ship locks at Sault Ste. Marie to Montreal.

Mr. Adcock: I move to strike out the answer of the witness for the reasons that I stated in the objection to the question.

Mr. Hopkins: That is all.

Re-cross Examination by Mr. Adcock.

Q. You say that on the drainage area of the Erie basin, there is a notoriously small run-off, do you?

A. I understand by the word "notoriously" one that is reputed to be of small yield.

Q. Have you ever computed the run-off yourself?

A. I have been very willing to accept the conclusions reached by Mr. Gardner S. Williams as indicated by his table LIXA, presented in this case, in which he derives a value for the run-off, from an examination and investigation, of 33 per cent.

Q. That is about 20,000 cubic feet per second?

A. Yes. I figure it 20,100; 20,000 is sufficiently close.

Q. That is slightly less than the 16 per cent. that you mentioned, somewhat less than the 16 per cent. of the total discharge of the Niagara River?

A. Yes.

Q. About 10 per cent.?

A. A little less than 10 per cent.

Q. As I understand it, figuring drainage areas, you calculate that there is a certain percentage of run-off for the amount of rainfall in a year, do you not?

A. That is one way of computing it, with a variation in the percentage with the amount of rainfall.

Q. That is as the rainfall varies, the run-off will probably vary, the precipitation?

A. Yes; that is I believe an accepted view.

Q. That is the larger the rainfall, the larger the per cent. of run-off?

A. Other things being equal.

Q. You have considerable data with reference to the average rainfall on the various drainage areas of the Great Lakes, have you not?

A. Yes, that is given in Mr. Wheeler's report 1903.

Q. And from that you can ascertain the relation of rainfall between the different drainage basins of the Great Lakes?

A. From the values given of the rainfall, we have some relative figures that will assist us in doing that.

Q. Isn't it a fact that relatively the rainfall upon the Erie drainage basin shown by these records is greater than on the other drainage basins, Michigan-Huron, for instance?

A. Mr. Wheeler, in his report of 1903, page 2861, gives the annual rainfall as a mean between 1882 and 1898, of 26.26 inches for Lake Superior; for Michigan-Huron, same period,

32.21; St. Clair-Erie, the value does not appear to be properly printed, but a deduced value is 34.08; and for the Ontario basin 36.87. This would indicate that the Erie rainfall is greater than the Superior and Michigan-Huron rainfall, as indicated in this tabulation, and less than the rainfall on the Ontario basin.

Q. That is about two inches less?

A. 2.8 inches less.

Q. If there is more rainfall on the drainage basin of Erie, it is reasonable to suppose that there is more rainfall on the lake surface than on the Michigan-Huron and Superior lake surfaces?

A. That would be a fair presumption. As the gages are on the shore line, just what the rainfall may be on the lake surface is not definitely known, that is the proportion it bears to the whole drainage basin.

Q. What data have you with reference to the evaporation, relative evaporation on the lake surfaces?

A. I think you know that I regard this matter of evaporation as a matter that our knowledge is not very definite about.

Mr. Adcock: I will ask the reporter to read the question. I move to strike out the answer of the witness.

Q. (Question read.)

Mr. Hopkins: If any?

Mr. Adcock: I didn't ask him that.

Mr. Hopkins: I have.

A. I will be very glad to read from these same tabulations of Mr. Wheeler.

Mr. Adcock: Q. I am not asking you to read. I am asking you what data you have with reference to the relative evaporation on the lake surfaces?

A. I read from page 2861—

Mr. Hopkins: He did not ask for that; he asked for your own knowledge.

Mr. Adcock: Q. I will add: Independent of discharge, so-called discharge measurements.

A. I should expect evaporation to be less on Lake Superior and Michigan-Huron, and less on Ontario than on Erie.

Q. You would expect it to be?

A. Yes.

Q. What data have you outside of your so-called discharge measurements? You know we do not want to get away from reasoning around in a circle, that you were so afraid of a little while ago?

3365

A. I have no independent data.

Q. You have no independent data?

A. No.

Q. What data is there outside of the deductions made from so-called discharge measurements?

A. Referring again to Table LIX A, of Williams' Exhibit 34, the full year run-off for Michigan-Huron is given as 0.866; Erie, 0.664 and Ontario, 1.440, indicating that Ontario is more than twice that of Erie.

Q. Mr. Shenehon, you are familiar, are you not, with the experiments on evaporation made by the United States Weather Bureau with reference to evaporation?

A. Well, not in detail. I have never felt that the conclusions that might be reached on the Great Lakes from any observations on tanks on shore, or the measure of the humidity, was conclusive evidence of the evaporation on the Great Lakes. I believe that is a thing yet to be solved.

Q. In other words, you have discarded those experiments entirely, have you? You did not think it necessary to study them in connection with this lawsuit?

A. In my evidence I think I said that in the physical analysis we could presume these values for the rainfall and evaporation to be sufficiently good to permit us to go on and test one river by interpolating in between. I used the values derived by Mr. Stearns in his tabulations.

Q. Do you understand that the evaporation from land drainage areas is subject to the same laws as evaporation from water surfaces?

A. Hardly.

Q. You have presented an exhibit here, Mr. Shenehon, has been marked Shenehon's Exhibit V. That was prepared I believe you said by your assistant, Mr. Souther on about November 19, 1913, in which the two hour lag was used, in preparing that exhibit. You do not think that is the correct value for the lag between Buffalo and Chippewa, do you?

A. The value I have more recently given is from two hours and 15 minutes to two hours and 40 minutes.

Q. And in connection with your preparation of certain figures here with reference to gage readings from November 1st, to 10th, 1907, at Buffalo and Chippewa, in which you took the mean of five hours, you used three hours as the lag?

A. Yes.

Q. As the value of the lag, Buffalo to Chippewa?

A. I had to choose in each case an even hour.

Q. You also used the same value for the lag in connection with the deductions from gage readings, Chippewa and Buffalo, August 3rd, to 12th inclusive, 1907, did you not?

A. Yes, on each of the two sheets which I presented today, I used a lag of three hours as the nearest even hour. In preparing these, I had the possibility of using both the two hour and three hour by including six hours altogether, but I thought it would be better in this investigation to compare five hours with five hours.

Q. The value of the lag is 50 per cent. more than the values which you gave earlier in your testimony, is it not?

A. Yes. They are each of them even hours; each of them is in error.

Q. You say that the readings are every hour, so that it is impossible to give us any intermediate time; but on those exhibits which were prepared by Mr. Souther, we found some instances where the lag was computed at two hours and a half, one hour and a half, five hours and a half, did we not?

A. Yes, and I can explain that I think. Where it was doubtful whether the peak was on a particular hour or the one following, he would take the mean of the two instead of taking either one.

Q. He exercised his judgment there, did he?

A. Yes.

Q. From the observations?

A. Yes.

Q. From the recorded gage readings?

A. Yes. There are very few of those, however.

Q. Now will you compute the Buffalo gage from the Chippewa gage, showing in a dotted line the computed Buffalo gage from the Chippewa gage and by a heavy line the actual elevation of the lake as shown by the Buffalo gage for the Three Curve Series?

A. You mean I am to prepare four sheets?

Q. Yes? You have the data, have you not from which the Three Curve Series was made?

Mr. Hopkins: For what period of time?

The Witness: I would protest against the method of determining the Buffalo gage in that way because it is inverting the order of things. The reason for the height of the Chippewa gage is the volume of flow caused by the elevation of the Lake Erie surface.

Q. As I understand from your examination previously, you stated that it was possible by this relation to predict the

height of the Buffalo gage from the Chippewa gage, did you not?

A. I may state right here that the 40 observations which I have indicated would indicate that you might predict the Buffalo gage from the Chippewa gage with a value which would be in the ratio of 1.00 to 0.56,—in other words you simply reverse the order in these statements I have made,—of course that means this would nearly double up, where you would be off a half an inch in predicting from Buffalo to Chippewa, in reversing the thing you would be off nearly an inch. Your predictions would bear about that relation?

Q. For the mean of say 48 hours at Chippewa, you could predict the Buffalo gage pretty closely, couldn't you?

A. Mr. Williams predicted the 24 hour means in many cases—

Q. I am asking you?

A. (Continuing)—within a quarter of an inch, and reversing the process, the Buffalo gage may be predicted by the same series of observations within half an inch, but of course in most cases it would be an inch or more.

You are using a short base line to get the larger quantity.

Q. I would like to have you make that computation that I asked you to make?

Mr. Hopkins: For what time?

Mr. Adcock: For the time covered by the discharge observations in the Three Curve Series.

The Witness: You mean hourly plottings?

Q. Yes?

A. (No answer.)

Q. Does the water abstracted by the Power Companies at Niagara Falls have any effect upon the level of Lake Erie?

A. A very minute effect.

Q. What would be the effect of the use of 56,000 second feet by the Power Companies upon Lake Erie? That is the amount I believe that under the treaty—

A. Let me understand exactly where you wish the diversion to be made.

Q. By the Power Companies.

A. There are two Power Companies at Niagara Falls whose diversions have absolutely no effect upon the elevation of Lake Erie; that is they take their water from well down in the rapids, below the cascades.

Q. Assume that it is above the cascades; assume that the additional quantity is above the cascades.

A. You mean the whole 56,000 is above the uppermost cascades?

Q. No, the excess of 56,000 over the present diversion is above the cascades.

Mr. Hopkins: In other words, what is the total present diversion?

A. About 20,000 cubic feet. I don't know exactly how much the Ontario Company is using.

Mr. Hopkins: I understand if an additional 36,000 is taken above the cascades.

Mr. Adcock: In addition to what is already taken.

Mr. Hopkins: I object to that question as not based on any hypothesis in the case. There may not be any 56,000 taken at that place rather than any other place.

A. I think there is no probability whatever of any such amount being taken above the uppermost cascades. If however, that amount were taken under the same conditions that the Ontario Company is taking its water, intercepting a sufficient amount of flow in the rapids and taking—

Q. I am asking you to assume that was taken under the same conditions as the American Company takes it.

A. If 36,000 second feet are diverted from the Grass Island-Chippewa Pool, under the same conditions as the two American Companies now divert their water, the effect on Lake Erie would be a lowering of approximately 2¼ inches.

Q. Plus or minus?

A. A lowering, I said, of 2¼ inches.

Q. The American Companies take about 15,000 feet now, do they?

A. 15,100. They are taking right up to their limit.

Q. They have lowered or will lower the level of Erie about an inch, will they not?

A. An investigation made and reported in the Preservation of Niagara Falls indicated that between my earlier measurements of 1898 to 1900, and the later measurements of 1907-'08, there had been no lowering whatever of Lake Erie from diversion at Niagara Falls; and the reason for that is that the Ontario Company had backed the water up a little by their divertor which was thrown out into the rapids.

Q. Assuming, as you stated, that 36,000 would lower it 2¼ inches, 15,000 would lower it a little over an inch, would it not?

A. Slightly less than an inch.

Q. How much would a diversion of 2,000 feet from Lake Michigan lower Lake Erie?

A. In the neighborhood of an inch, a little over an inch; 1.1 inches roundly.

Q. That is based upon your increments that you have been talking about heretofore. Is that correct?

A. Yes, that is having in mind U. S. Exhibit Number 3.

Q. When you took those longer periods, 20 hour periods in making your reductions to predict the elevation of Chippewa from the Buffalo gage, you did that to eliminate so-called oscillations of Lake Erie, did you not, sudden oscillations like those occurring in an hour or two hours?

A. The exactness of the prediction is the evidence of that; and an examination of the results I think should be rather conclusive on that point.

Q. It was for the purpose of eliminating the effect of the oscillations in Lake Erie, was it not?

Mr. Hopkins: The question is what was the purpose of taking the time?

A. The reservoir effect in the river between Chippewa and Erie due to changes—or, if you may wish to speak of that as oscillations in Lake Erie, is the reason why a 20 hour period gives more exact predictions than a five hour period. It tends to eliminate the effect of oscillations.

Q. If the Buffalo gage were at an even elevation for a number of hours, say 24 hours, and assuming a straight line as you might plot them, or horizontal line, approximately horizontal, and the Chippewa gage were in the same position, that is with reference to these horizontal lines, for a number of hours, you would then consider that the river was in equilibrium, would you not?

A. Yes. Where Lake Erie is quiescent over a period of hours and the flow in the river becomes a steady thing, then we speak of it as being in equilibrium.

I think I would like to speak of the back water effect due to say three inches abnormal elevation at Chippewa, the effect it would have on the floor. The backwater effect has a value of roundly 20 per cent.; now .25 of a foot, which is the decimal expression for three inches, would mean .05 of a foot on the Buffalo gage; and that is equivalent to 1100 cubic second feet, or ½ of 1 per cent. of the normal outflow. And you will notice in the five hour periods that I took, in the worst month of the year, November, that there was just one case where the maximum deviation of Chippewa from its predicted value was as much as 2.7 inches.

Mr. Adcock: That is all, subject to the other question.

Adjourned to Wednesday, May 20, 1914, 10:00 o'clock A. M.

FRANCIS C. SHENEHON resumed the stand and further testified as follows:

Further Re-cross Examination by Mr. Adcock.

Q. On your previous examination, Mr. Shenehon, you were asked to make certain computations; that is to compute the elevation of Buffalo gage from Chippewa based upon the formula which you had derived as the relation between Buffalo and Chippewa. And I have before me four sheets which purport to be plats which I understand have been prepared by you, covering the dates named upon the so-called Three Curve Series. I ask that the Commissioner mark these papers Shenehon's Exhibits E1, E2, E3 and E4, Cross Examination. (Sheets so marked.) These papers that have just been marked, have been prepared by you, have they, Mr. Shenehon?

(Sheets referred to in above question were here marked Shenehon's Exhibits E1, E2, E3, and E4, Cross Examination.)

A. Yes, prepared by me personally except one sheet on which I employed a draftsman and I checked his work sufficiently to feel sure that it is correct, substantially correct.

Q. Now the curve which appears at the top of these different sheets as the black line is the observed elevation of Buffalo gage, is that correct?

A. Yes, and that means each hourly elevation is plotted and a scale made of height and time.

Q. And the red line is the computed elevation of Buffalo with reference to the Chippewa Gage, is that correct?

A. Yes, that is true.

In your question you asked me to plot that in the form of a dotted black line. I found that the predicted elevation and the computed elevation were interwoven so much that it was difficult to distinguish the black dotted line, and so plotted it in red. If you wish it done, I can go over that with a solid dotted line.

Q. The red line shows the computed?

A. That is the predicted, the computed elevation.

Q. From Chippewa gage. And you use there your law, the one that you have testified to?

A. Yes.

Q. What was that by the way? That is if Chippewa changes say one foot, you expect that Buffalo will change a certain amount?

If Chippewa changes .56 of a foot, Buffalo changes one foot. That is the ratio.

Q. That is the ratio?

A. Yes.

Q. Of course we can see can we not, Mr. Shenehon, whether this red line is so interwoven with the black line that it would be impossible to distinguish a dotted black line, can we not?

A. That may be done as you wish. I will point out specific cases where the difficulty appears.

Q. For instance at noon on June 29, or between noon and six o'clock on June 29, they would not be interwoven very much, would they?

A. There are cases where they are very sharply and clearly apart, and I imagine in cases they would be as much as six inches apart in lake elevation; those sudden changes, either rising or lowering.

Q. Referring, again, to October 22, about noon of that day, and in fact covering October 21, and October 23, the red line is not interwoven very much with the black line, is it?

A. October 21 and 22?

Q. 22 and 23.

A. Those are fairly distinguishable.

Q. That is you can see that the red line is some distance from the black line there, can you not?

A. Yes, it is 1/10th of a foot in lake elevation different in a good many cases on those three days. In some cases it is as much as .3 of a foot, nearly 4 inches.

I might call your attention however,—

Q. I will ask you further questions, Mr. Shenehon, if I may have those exhibits, all of them, after you get through.

A. You understand, Mr. Adcock, I can go over this with a dotted black line if you prefer to have it in that way, after you have investigated whether or not it is going to confuse the plot.

Q. It does not make any difference, Mr. Shenehon; a red line is just as good as a dotted black line. In fact, on the 26th and 27th of October, the 28th and 29th, the 30th and 31st, November 1st, November 2nd, the lines are not very close together, are they?

A. That was commencing October 30th?

Q. No, before that?

A. Yes, the lines on the 27th, they coincide over a period of about six hours, so that they would not be clearly distinguishable. The lines cross; that is the line of actual elevation is crossed by the red line, the predicted elevation, in a number of cases on the 29th.

Q. But you can see some space between, can you not?

A. In some cases they actually are superimposed.

Q. That is the six hours that you have mentioned?

A. Yes. And in other cases the lines cross, indicating that the predicted at that point is exact.

Q. Of course the court can see that too, can it not?

A. Yes.

Q. Then on August 4th, 5th and 6th, the red line and the black line are not very close together, are they?

A. There are considerable divergencies on the dates mentioned. That was the last sheet plotted by me, and there are sharp changes of elevation on those three days, which indicate a large movement at Buffalo, where the movement predicted from Chippewa would not indicate that.

Q. Well, the result of it is generally, is it not, from those plottings, that the computed elevation, the predicted elevation is lower at the high points and higher at the low points than the actual observed elevation?

A. Yes. That has been repeatedly stated by me I think in my testimony.

Q. You agree to that proposition, do you?

A. Oh, sure.

Mr. Adcock: There are a few questions I would like to ask Mr. Shenehon further on cross-examination.

Q. Over how long a period of time did your several current meter ratings last at the reservoir at Buffalo, and through the ice?

A. I should have to refer to the records to answer that question, Mr. Adcock.

Q. Have you any recollection at all as to the period of time?

A. We would spend two to three days at a time in ratings, and the ratings were perhaps a month or two apart. I should wish to refer to the report of 1900, for a specific statement concerning that. You are referring to the Niagara River now, or the general practice?

Q. The Niagara River?

A. (After referring to report.) I find that for the L. S. 2 B Meter, this was rated on a still water base in September, 1898; in July, 1899, at the reservoir in Buffalo; in September and October, 1899, same place; in November at the same place; also in February, 1900, at the reservoir at Buffalo.

I find for the L. S. 4 A Meter, that it was rated in July, 1899, at the reservoir at Buffalo; September, October, the same place.

Another equation is given for October, 1899, November, 1899, and February, 1900. Now my recollection as to the time would be anywhere from two to three, possibly four days. I hardly think it was as long, however, as four days, ordinarily.

Q. What table do you refer to, Mr. Shenehon?

A. I refer to table 4, summary of meter readings, on page 5339 of the report of the Chief of Engineers for the year 1900.

Q. Does that table indicate all the ratings of the meters that were made?

A. Up to the date, February, 1900. I am not certain whether another rating was made prior to leaving, in June or July of the same year, or not.

Q. But that includes all the ratings that were made up to the date of the report?

A. Those are all the still water ratings. Of course other ratings were made in the river itself, side by side, comparisons which are of a somewhat different nature.

Q. How frequently was the meter cleaned and oiled during the ratings, these two or three days that you speak of, that is each meter?

A. Why I should say as often as two or three hours. You must remember you are asking me something about what occurred 15 years ago, 14 years ago. I can't give you down to the last minute.

Q. How many revolutions, or how many feet of current travel was there between oilings in ratings, including both recorded and unrecorded revolutions?

A. That would be a different thing to get at. Roundly, 2.4 miles.

Q. That is between each of the oilings?

A. That of course is approximate.

Q. That is approximate?

A. I should add that if anything were wrong with the meter, as sometimes did happen, it was necessary to take it up, then it was generally oiled.

I wish to be understood however as saying that in my practice, very little oil was used; nowhere near the quantity of oil indicated by Mr. Haskill in his statement. Our practice was to put just a little oil on the very tip of the pivot, both in rating and in the river work.

Q. Did you take it apart to do that?

A. You have to take off the wheel, yes; that is the wheel is raised from the pivot.

Q. It hasn't any self oiling system?

A. Oh, no.

Q. How frequently was the meter cleaned and oiled during the Niagara gaging?

A. Why at the beginning and end of the discharge observations ordinarily. Sometimes, where anything went wrong in between, then the meter was also raised as in the rating and the wheel taken off, and any trouble investigated.

Q. How often did you have trouble?

A. Oh, it was not very frequent. In handling the two meters, I think ordinarily we would not pick up a meter during a discharge measurement for that purpose. I am thinking now of the work on the catamaran in the Open Section.

Q. How about the International Bridge?

A. There of course the meter was picked up between each measurement at the station.

Q. And oiled?

A. No, not oiled unless it was indicated. When I say indicated, the reason for oiling was ordinarily what is known as a skipping, a few too many registrations, coming from a little oil getting on the silver or platinum disc. And that was infrequent. That was the reason why I used so little oil, so that that should be infrequent.

Q. How often did you have trouble, every hour?

A. I should say not. I should say that was—

Q. Every two hours?

A. I should not think it would average over every two hours, possibly not as frequently.

Q. Would you oil it every time you had trouble?

A. Whenever we took off the wheel and wiped off the disc, it was customary to touch the cork of the watch oil bottle to the pivot, put a fraction of a drop of oil on the pivot.

Q. A fraction of a drop. What fraction?

A. You would not put what would drip from it. We would tilt the bottle up, and a little oil would remain on the cork that we would touch on the pivot of the meter.

Q. You did not use an ordinary oil can?

A. No, we used watch oil; used it in that way, worked right from the watch oil bottle.

Q. You oiled it by means of a cork, what little oil remained on the cork?

A. We upset the bottle, you understand, with the cork still in, and turning the bottle up, touched the cork with the adhering oil to the pivot.

Q. Did you ever run for a day without having any trouble?

A. In running for a day, the meter would be oiled at noon after the completion of a discharge observation.

Q. That is in case you had no trouble, you would oil at noon, and then again at night?

A. Yes, and if we were measuring discharges, if we got across the river and started back, we would ordinarily overhaul the instruments before starting back.

Q. That is between each discharge measurement you would oil the meters, is that correct?

A. Yes.

Q. In your gagings of the Niagara River at the International Bridge Section, how many miles of current travel were there past the current meter between oilings, including both recorded and unrecorded?

A. Well, it would be quite different on the Bridge Section from the Open section. You refer to the Bridge Section?

Q. I am speaking of the Bridge Section now, Mr. Shenehon?

A. On the Bridge Section; this statement must be approximate, of course.

Q. Certainly?

A. That would be about three miles.

Q. On the Open Section, what was it?

A. That might be a little more than three miles because I did not in that computation take account of the unrecorded. There should be a little more added to that.

Q. It would be pretty near double, wouldn't it?

A. No, I think not. No, it would be the time of lowering the meter and raising it, which is a very short time. No, I should say possibly 3½ miles would be a fair statement of that.

Q. That is in the course of making a discharge measurement when the meter would turn and there was no record made of its revolutions?

A. That would be the time that we are lowering the meter from the water surface down to the .3 depth.

Q. Down to the .4 depth?

A. In the International Bridge, it is .3.

Q. There were how many stations there, Mr. Shenehon?

A. Twenty-one stations.

Q. It is your proposition that in making the discharge measurement the meter would only run a half a mile, in lowering and raising it to the .4 depth at each of the 21 stations?

A. Well, I figured that we made two 2 minute observations, that is four minutes on the station where the meter is wound up. You see in the deepest point .3 is only 15 feet, and the meter is lowered fairly rapidly, and as soon as the observation is completed, it is raised very rapidly.

Q. How soon after the meter is lowered to the depth—.3 depth, is it not?

A. Yes.

Q —do you commence to take the record?

A. Immediately.

Q. That is on the instant?

A. I don't mean on the instant.

Q. It would be half a minute?

A. Let me figure this now: This is a statement that is made approximately. Let's see how much that would be. I said $3\frac{1}{2}$ miles of which three were kept in the regular recorded observation. That would be, four minutes would be 240 seconds; 1/6 of that would be 40 seconds; that is the half mile is 1/6 of the three miles; that would be 40 seconds. That would be 20 seconds for lowering and 20 seconds for raising, which is reasonable. It is fairly close to that.

Q. 20 seconds for lowering and 20 seconds for raising; and also in the 20 seconds after lowering, you would have commenced to get your record too, would you?

A. Well, if we are going to make these corrections and make it with the utmost refinement, I should add something considerable to what I have given you for still water ratings. I have given the actual revolutions that were recorded. You see we made a run on each side of the base going both directions. I should add 50 per cent. at least to that. It was a 200 foot base. We begin at least 50 feet back and we would run at least 50 feet over the base, so where I stated a travel of 2.4 miles it should be 3.6 miles.

Q. What percentage of the time was the meter out of the water during the period of a single discharge measurement at the International Bridge?

A. About two hours was a normal time for discharge, and if we observed four minutes at each station, that would be 84 minutes; leaves 36 minutes for the raising and lowering of the meter and the move between stations.

If you wish to get this with all the revolutions of the meter, I am afraid I can't give it to you because sometimes there would be wind blowing while the meter was being raised from the water surface to the bridge, and the wheel would spin. That would be true also in rating, in our preparation of the meter. You see it is rather difficult to get a determinate, comparable statement of these things. I see what you are getting at, and I am going to help you all I can, but you see I can't tell you very exactly about that.

Q. You still maintain do you Mr. Shenehon, that the meter only ran half a mile?

A. I should think that was a fair estimate and we did not take into account any spinning in the air. There should be a little added for that.

Q. You are also considering the 21 stations at the Bridge Section?

A. Of course in the end it does not make much difference whether there is oil on the pivot or not, within a reasonable limit.

Q. What was the average current at the Index Point?

A. Well, I have, in this rough computation, taken four feet per second.

Q. You have taken four feet per second as the average, have you Mr. Shenehon?

A. Yes. I think that is on the low side.

Q. You think that is on the low side?

A. I think I should add about ¼ to that statement, bringing the velocity up to a mean of about 5 feet per second. Now let me see where that goes to; that would be 3½ miles; ¼ added to that would be 4.37. Yes, that would be about 4.37.

Q. That is not allowing anything for the raising, for the time the meter was moving?

A. Yes, that is true.

Q. What is your estimate of the miles of travel of the meter, that is the recorded travel?

A. I make 4½ miles the travel on the rating base and 5½ miles the travel on the International Bridge Section in a discharge observation.

Q. How much was meter B pulled upstream at the International Bridge at depths of 10, 20, 30, 40 and 50 feet, in Spans 3, 4 and 5?

A. My recollection is in coefficient work that we pulled it up from 8 to 10 feet.

Q. At all these positions?

A. I don't recollect in detail what we did at a particular station. That amount of upstream pull would not be required, in my judgment, in more than a few of the spans, those deeper spans.

Q. How was it in gagings, discharge measurements?

A. In discharge measurements there was no pulling of the meter upstream. The meter with the heavy 136 pound weight dropped from the rail of the bridge, over the rail of the bridge.

Q. How many miles of travel were there, current travel,

between oilings of the meter in coefficient work at the International Bridge Section?

A. I can't give you definite figures on that, Mr. Adcock.

Q. Well, approximately?

A. I should say it was much the same as in discharge work; possibly a little more frequent.

Q. More frequent oilings. You had more trouble?

A. I say "possibly." No, we were using two meters at the International Bridge where we used one in the discharge work.

Q. I wondered why you oiled it more frequently in coefficient work?

A. I don't know that we did.

Q. Did you pull your meter out of the water and oil it before you got through a vertical?

A. Before we got through a single vertical?

Q. Yes?

A. Not ordinarily, no.

Q. How long would it take you to make your observations in a single vertical for coefficient work.

A. That was different lengths of time.

Q. Would you oil it before you went to another station?

A. Not necessarily, no.

Q. You did not have any regular practice about that in the coefficient work?

A. The meters were ordinarily always oiled before starting out in the morning and always in the afternoon.

Q. Before starting out after dinner?

A. If there was any reason why it should be overhauled between times, it was done.

Q. When you say if there was any reason why it should be oiled between times, you mean if there was any trouble?

A. Yes, sometimes the connection, you understand there was trouble with the connections.

Q. If there was not any trouble then you oiled it before going out in the morning and after dinner before commencing your work in the afternoon, is that right?

A. Yes, that was the regulation, to always oil the meter at those times and such other times as might be required. When I say "required," you understand that a meter is an instrument that is clicking just as intelligently to the observer as a telegraph instrument tells the operator what the message is. We know what is happening down in the water very accurately. We know when a little oil gets on the disc,

and we have the sharp double click breaking into the regular rhythm of the spinning of the wheel. We know when the water is turbulent. When we get into an eddy, we can tell immediately.

Q. You would not oil it when you got into an eddy?

A. No. I am explaining that there are reasons why we know we need to bring up the meter and overhaul it, and it is because this spinning wheel with the electric connection is telegraphing the message to us constantly.

Q. Then the operator would have to use his judgment as to when he should oil?

A. The same judgment that the telegraph operator uses.

Q. Now Mr. Shenehon in the Open Section, you said the time of travel between oilings was very different from that at the International Bridge, did you not? You mean it was shorter or longer time of travel?

A. That differed. Certain of the measurements in the Open Section were made while coefficient work was going on. In other words we would observe eight minutes on a station. In such a case, it would take longer to get across the river; and other times, of course, we made observations much the same as at the International Bridge, two 2 minutes runs. So which time do you refer to in your question; where we are taking coefficient observations at the same time?

Q. I wanted you to explain just what the difference was?

A. In the case of the Open Section, the meter would not be raised from the water between stations, so during the two hours or longer which it took to take a discharge observation the meter wheel would be spinning. If you can get the mean velocity of the current, that works out in that case. That might be a way to get at it.

Q. You testified as to the derivation of increments for the St. Lawrence and St. Clair Rivers, using the Niagara increment and the Lake Erie run-off. That was on your re-direct examination. When was that computation made?

A. I never have made any computation of that kind.

Q. What computation did you make then, using the run-off of the Lake Erie Basin?

A. I made a computation in which the consistency of the volume of flow of the—

Q. That is the discharge of the Niagara River?

A. Yes, as compared with that of the St. Lawrence River, by introducing the local supply as computed by Mr. Stearns in his Exhibit Number 1, I think it was, using 16 years; be-

ginning in 1891. Another computation was made in which I took the run-off as given by Mr. Gardner S. Williams in his Exhibit 34; that is an average.

Q. Sheet 5 of table 69e?

A. I have not the exhibit before me; 59, I think it is.

Q. 59?

A. Using table 59a, of Williams' Exhibit 34, and the period June to November. This gives the average run-off of 0.924 cubic feet per second per square mile of drainage area for Ontario.

Q. Did you examine table 59e, sheet 5, in that connection?

A. Sheet 5, of table 59e, pertains to the run-off of Lake Erie rather than Lake Ontario. Is that the one you wish to refer to?

Q. Yes?

A. I have this table before me. I have never very carefully examined the details of any of these sheets. The conclusions appear to be in consonance with the volumes of flow of the rivers and that appeared to me sufficient.

I should add, however, that the method of getting at the thing is to my mind the correct one, examining the run-off of the streams in the lake areas themselves, just as Mr. Stearns examined the run-off of the streams in Massachusetts, New York and Pennsylvania.

Q. I call your attention to the tabulated discharge of the Maumee River from July to November, shown on sheet 5, of table LIXc, Williams Exhibit 34. What is there shown as the area, drainage area above Waterville?

A. 6,111 square miles.

Q. What is the recorded run-off from this area for July, 1899?

A. 285 cubic feet.

Q. What is this per square mile?

A. That is 0.046.

Q. What is the run-off for August 1901?

A. 47 c. f. s.

Q. What is this per square mile?

A. A little less than 0.008 cubic feet per second per square mile.

Q. What is the run-off for September 1900?

A. 27 c. f. s.

Q. Or 0.0044 c. f. s. per square mile?

A. Yes, about that.

Q. That is pretty small per square mile, isn't it?

A. Yes.

Q. Hardly conceivable?

A. Well, I have lain at anchor in the Maumee River, with practically no current running.

Q. Was that in the canal or the channel of the Maumee River?

A. That is at Toledo, in the Maumee River.

Q. Did you ever lay at anchor in the canal?

A. No.

Q. Did you know there was a canal there?

A. At Toledo?

Q. No. In the Maumee River?

A. No.

Q. Paralleling it. What for September 1901, was the run-off?

A. 42 c. f. s.

Q. And per square mile that would be what?

A. About .007.

Q. For October, 1899?

A. 48.

Q. About .008 cubic feet per second?

A. That would be about .008.

Q. For October 1900?

A. 41. That would be about .007.

Q. And for October 1901?

A. 246.

Q. .04, is that right?

A. Approximately .04.

Q. And for November 1901?

A. 98 cubic feet per second, about .016.

Q. Do you think it possible that 6,111 square miles of drainage area on the Maumee River should only contribute from .0044 to .047 cubic feet per second per square mile, when the average of all the rivers, the Maumee included, as shown in table LIXa, is never less than one hundred and twenty-six thousandths cubic feet per second?

A. I imagine the error of observation enters into these observations, as all others.

Q. You said you did not know anything about the canal paralleling the Maumee River near Waterville, from which large quantities of water are used for power purposes?

A. No, I am not familiar with that.

Q. In view of this condition as to the run-off records from about 50 per cent. of the measured area of Lake Erie, upon which would you place the greater reliance, the records as

published by the United States Geological Survey and embodied in Table LIXa, Williams' Exhibit 34, or a run-off derived from rainfall observations as used by Mr. Stearns?

A. I think the best values we have for determining the relationship, that is the local supply of Lake Erie are from the finely gaged rivers, St. Clair and Niagara; and I think the best basis we have of determining the local supply for Ontario is the Niagara and the St. Lawrence Rivers. There are not any others comparable in precision to those, in my judgment. You are asking me a question regarding the local supply.

Q. I asked you a question, and I hoped that perhaps you might answer the question that I asked you. I did not understand that your counsel had asked you any question which would require an answer.

A. Will you please read the question?

Q. (Question read.) You told me something about comparing the Niagara discharge and the St. Clair discharge. I have not asked you anything about that. I am asking with reference to the run-off data as compared with the rainfall data.

A. I think it is understood that Mr. Stearns used a similar method to that used by Mr. Williams in getting out his formula which he applied to the Great Lakes, and made an estimate. Mr. Stearns, as I understand it, used such stream gagings in New England, Pennsylvania and New York as were available. Mr. Williams uses a similar method, only he uses the streams in the basin of the Great Lakes themselves, instead of alien streams, streams not in this basin.

Doubtless the streams used by Mr. Stearns were somewhat in error. I imagine that the final conclusions of Mr. Williams are likely to be in error possibly as much as 33⅓ per cent., and the error of observation is certainly present in all of these stream gages. Now, I believe Mr. Williams' method was a correct one.

Q. That is you would place greater reliance on that?

A. Even considering the little flow as indicated, pointed out.

Q. That is the extraordinary conditions shown on the drainage area of the Maumee River?

A. I rather persist in feeling that my earlier answer to your question was a correct one, because I must take into consideration all the things that do affect my judgment in these matters.

Q. I have asked you to take into consideration certain specific things. Then you place the greater reliance upon the

United States Geological Survey records, shown in table LIXa?

A. Yes. They check, from the results gotten out by Mr. Williams, they check very closely the volumes of flow of our records, and that really is the big test we have of the physics of the Great Lakes. What the local supply is is best tested by the flows of the rivers of the basin itself.

Q. When did you make that computation?

A. The first computation between the Niagara River and the St. Lawrence was made at the time of the cross-examination of Mr. Freeman, I believe. It was introduced, I think, in his cross-examination.

Q. You did not make a computation with reference to that matter until after Mr. Williams had testified in this case, did you?

A. No, that is true; until both Mr. Stearns and Mr. Williams had testified.

Mr. Adcock: I think that is all.

Further Re-direct Examination by Mr. Hopkins.

Q. Mr. Shenehon, in these computations that were made from the Chippewa gage to the Buffalo gage, you were still taking the hourly observations were you not and plotting them according to the method requested by counsel for the defendant?

A. Yes, they are from the records of United States Lake Survey, the hourly readings at Chippewa used as a basis of deriving the elevation of Lake Erie; and I used in this connection a lag of two hours.

Q. You did not have the data showing the elevation of the 59 minutes between the hours, or for all the time between the hourly periods, did you?

A. No.

Q. And in your direct testimony in this matter, you testified that you could get a certain degree of accuracy using daily means, did you not?

A. Yes, 20 hour means, I think I used in a statement in my re-direct testimony, and then I used also five hour means, and of course those same predictions made of the elevation at Chippewa can be reversed by taking the reciprocal of 56 as a basis. In other words, where I stated that the check between Buffalo and Chippewa was 1 inch, where we are deriving Chippewa from Buffalo, it would be about 1.8 inches where we

reversed the process. That is the ratio of 1 to 56 is 1.78 roundly. It would be rather interesting to simply reverse those predictions for the months of November and August, that I put into my re-direct testimony. It would indicate that in five hour periods how fairly close you can predict the elevation of Lake Erie at Buffalo from the elevation of the water surface at Chippewa, which is 20 miles down the river in distance and is down about 10 feet in elevation. It is remarkable, and I should be very glad to compute those and put them into the record.

Mr. Hopkins: We will reserve any further examination.

Further Re-cross Examination by Mr. Adcock.

Q. You say you used a two hour lag?

A. Yes.

Q. I thought we convinced you sometime ago that it was not two hours exactly. Have you gone back to the two hours?

A. This matter of lag, the exactness of it has very little bearing really on the questions at issue. I believe I said that the lag, in my judgment, was somewhere between two and three hours, and two hours and 40 minutes seems to me a very good value.

Q. If I recollect Mr. Shenehon,—I may be mistaken; your memory may be more correct than mine,—but I understood you to say you put the minimum at 2 hours and 15 minutes; the maximum at 2 hours and 40 minutes?

A. Let me state one other thing—

Q. Is that a fact?

A. Yes, that is the truth. Let me add one other thing: In the exhibit which I put into this case, Shenehon's Exhibit V, on cross-examination, the lag was two hours on that, and in order to keep the series much the same, this you see is a reverse process of the same thing, it seemed wise to make that two hours.

Q. In other words two hours was your story, and you are going to stick to it?

A. I think the testimony is pretty full on that subject.

Further Re-direct Examination by Mr. Hopkins.

Q. Why doesn't the lag make much difference?

A. The changes are ordinarily so slow that whether you take 2 hours or 2 hours and 40 minutes, or 3 hours between

Buffalo and Chippewa, really is of little consequence. I think an examination of these exhibits which have been put into the case this afternoon will indicate that two hours is fairly close, and possibly it will indicate also that 3 would be a little closer; but it is not a matter of any large moment. It does not enter into any of the real issues of this case, in my judgment. You understand within these limits I am mentioning at Chippewa, whether we take two hours or three hours is of no great consequence.

Further Re-cross Examination by Mr. Adcock.

Q. You think if you had taken 3 hours instead of 2 hours, it would be somewhat more exact?

A. I think it would be a little closer but not very substantially.

Q. If you were going to make up a series of exhibits such as you have made up heretofore in this case, you would take 3 hours rather than 2 hours?

A. I think I would, yes. You remember that I remembered a thing that I had forgotten, that we had before used 2 hours and 40 minutes in some previous computations.

Further Re-direct Examination by Mr. Hopkins.

Q. Mr. Shenehon, what difference if any would it make whether or not a meter had been oiled after it ran two miles, three miles, four miles, five miles or six or any other length, within a reasonable period?

A. Referring now to these large Haskell meters, the A, and the B, types, where the wheel is a little over seven inches in diameter, and this wheel is spinning like a thimble on a needle, the pivot gives very little friction and running in the velocities, a mean velocity say of five feet such as we have been considering, the current is so powerful that that friction is really of little moment.

In my judgment there would be substantially no difference whether we had any oil on the pivot or not. The principal friction or resistance in turning comes in in the bearing of the contact pin on the disc that I have already spoken of. That has some moment. In other words, it is a little distance from the axis of revolution, and that is the real critical thing that determines a change in rating.

Further Re-cross Examination by Mr. Adcock.

Q. The meter is a pretty delicate instrument, isn't it?

A. Yes, but as I previously stated, it is a fairly strong one, also.

End.